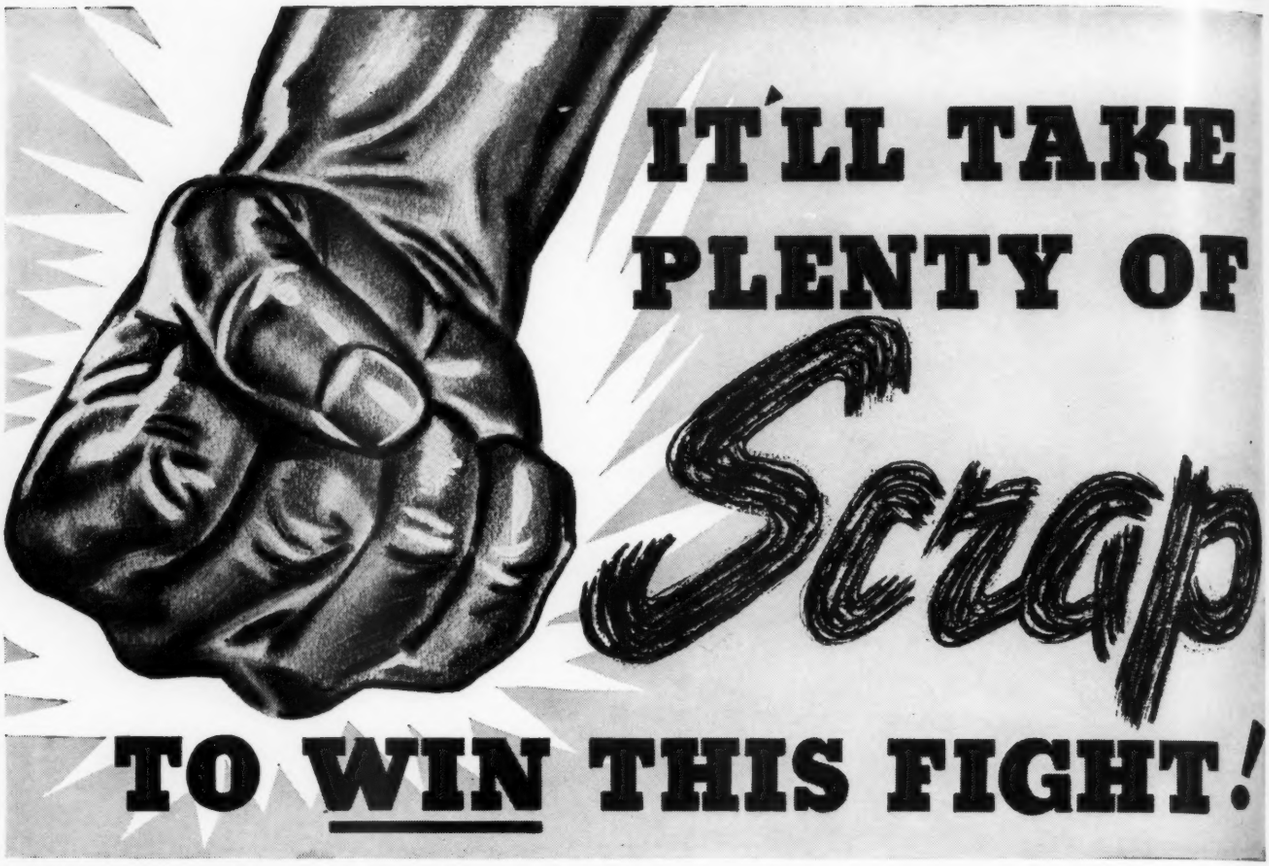
PRODUCT ENGINEERING

SEPTEMBER, 1942

The Amazing IMITATORS

Found in Japanese Planes Shot Down at Pearl Harbor — December 7, 1941

NAME OF PART	COPIED FROM
Engine Cylinders	Wright R-975-7
Valve Mechanism	Pratt & Whitney
Generator	Eclipse Type G-1
Fuel Pump	Romec Type F-4
Propeller	Hamilton Standard
Compass	Fairchild
Gauges	U.S. C
Oil Strain	



3 Million Tons of iron and steel scrap are wanted every month . . . Are you doing your part to help America win her battle of production?

CONSERVATION AUTHORITIES RECOMMEND THESE 8 STEPS TO GET IN THE SCRAP

1 Put some one individual in charge of scrap in all departments of your business and GIVE HIM AUTHORITY TO ACT.

2 Comb the plant and yards for dormant scrap, abandoned equipment, old boilers, pipe, moulds, obsolete dies and parts, material now being destroyed which has salvage value.

3 Survey all plant equipment, particularly idle standby or discarded machines, with a view to applying or converting them to useful production.

4 SEGREGATION:
Identify, classify and segregate scrap and supervise its handling to avoid contamination. This will increase its value.

Provide separate containers, clearly marked, tor each class of scrap material.

Repair or rework worn or broken cutting tools Keep unusable small pieces and turnings segregated. Even high speed steel grinding dust is valuable.

Dismantle discarded equipment promptly into its components—electrical, fastenings, lumber, etc.—so that these parts may be utilized or scrapped.

Sort blanks, short ends, cut-downs, clippings, etc., for possible reuse for smaller parts made in the same or other departments.

Recover and reclaim used cutting oils, lubricants, surplus paints and spray finishes.

Sort sweepings and miscellaneous waste to recover scrap values.

5 Constant reminders in the form of posters, illustrations of right and wrong methods, pay envelope enclosures, house organ publicity, etc., are potent aids to the conservation program.

6 Release for scrap, obsolete engravings, electrotypes, and standing types for catalogs, forms and advertising material.

7 Inspect all refuse to detect avoidable waste and excessive rejections. Educate production executives to correct such conditions at the source.

8 For information and assistance on special phases of conservation and salvage communicate with Industrial Salvage Section, Conservation Division, War Production Board, 9th Floor, Washington Gas Light Building, Washington, D. C., or with nearest regional office

The metallurgical experience of our technical staff is available to aid you in these and other technical phases of metal salvage.

KEEP SCRAP MOVING INTO WAR PRODUCTION!

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK, N. Y.

PRODUCT ENGINEERING

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IN THIS ISSUE

America's Liberty Ships

Liberty ships have stood the test Their performance is better than that which was expected. They are sliding off the launching ways in ever increasing numbers. Some idea of the efforts being put forth by the United States Maritime Commission and the shipyards of the country to accelerate the production of seaworthy cargo ships can be obtained from this month's lead article. It tells how modern shipbuilding technique and American mass-production methods have reduced time and manpower necessary to fabricate and manufacture materials and parts, and to construct cargo vessels.

Designing Molded Plastic Parts

Increasing experience in plastics applications and design, new plastic materials, and improvements in molding technique, all serve to standardize and bring about agreement among engineers as to approved design practice. The article by Horace C. Hillman, beginning on page 498 and the Reference Book Sheets on pages 545 and 546, contain a wealth of up-to-date data on the properties of plastics and give design precautions that can be relied upon in designing molded plastic parts.

Photographic Range

One of the often vexing questions when taking a picture of a machine is how far away to put the camera in order to get the details as large as possible. A. C. Rasmussen, on page 493 of this number, gives a simple way to calculate the optimum distance from camera lens to object. It takes out the guess when trying to get maximum coverage on the film.

The Amazing Imitators

The tricky Japs developed an unusual technique in copying American designs of military planes, as described in this article (page 504), based on a report by engineers of the Army Air Forces. The sons of Nippon were not satisfied

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to make faithful duplicates, but selected what they considered outstanding design features in each of a number of American designs of the engine or device they were imitating. The amazing thing is that their finished designs were good. The big question now is whether or not the Japanese have enough able engineers to match the progress being made in designs of American military planes. The article gives some answers to this important question.

Wartime Designs and Developments

One of the biggest factors contributing to the success of American industry in its gigantic war job is the special production machinery designed to do things in a big way. One such machine is the Snyder fin-miller, a special single-purpose machine to produce the fins on the cylinder barrels of airplane engines. Details of the design of this machine, amazing in its simplicity, are given on pages 507-510 in our new section "Wartime Designs." The ingenious hydraulic and electrical circuits of this machine are noteworthy and might find application in principle on other equipment.

Impact Vibrations—II

Following up the analysis of the physical laws of vibration damping and the study of the properties of materials used in energy damping installations that was presented in the August issue of P.E., Leon M. Dekanski tells in Part II of the article, pages 515-518, how to derive equations for the calculation of displacements, load on the energy damping element, and the reaction of the ground.

Thermal Insulating Materials

Many types of industrial and domestic equipment depend for their economic operation upon the use of insulating materials for the maintenance of a desired temperature. This objective is obtained, of course, only after the engineer has made a study of the properties of the materials available. S. V. Saginor in his article on pages 494-497, describes the field for various insulants, their characteristics and methods for their application. A good article for the engineer to have in his data file for handy reference.

Testing Small Springs

A spring design job is not always finished after load and deflection have been determined. There remains the job of determining how long the spring will last before it breaks or before its "set" exceeds the required limits. John Cavanagh, of Kenney Manufacturing Company, has devised test equipment (an old filing machine, a revolution counter, a door bell and relays) that can be rigged up by any design and research department. Details of equipment and procedure are presented on page 520.

Designs With Different Material

Before aircraft structural design influenced the thinking of engineers, and designing for minimum weight was not essential, it was usually assumed that the weight of a structure would be directly proportional to the weight-strength ratio of the material used. Now, thanks largely to more exhaustive stress analyses by aircraft designers, this assumption has been pretty well discredited. Some of the other stress factors whose analyses have made possible competitive light-weight structures in steel, aluminum, plywood, plastics, and magnesium are discussed in the article starting on page 530.

Synchronous Motor

A new miniature (2-in. dia.) synchronous motor has been designed by Westinghouse for meters, recording instruments, and similar applications. The new motor eliminates necessity for high-speed gearing since it operates at 600 r.p.m. on 60-cycle circuit and uses the hysteresis principle. See page 502 for its description.

Multi-Field Pilot Generator

Performance regulation, a refinement in speed control of electric motor-operated equipment, is being required in an increasing number of applications where closer regulation of speed is desirable, such as in the operation of paper-making machinery. This article explains an improved method of speed control made possible by a small accessory generator which regulates the field current of the main d.c. generator supplying power to the motor. Its principles of operation and typical circuit diagrams are described by C. W. Drake, Westinghouse engineer, beginning on page 521.

Design of Forgings

E. F. Burton, chief engineer of Douglas Aircraft Company, called our attention to the fact that the bottleneck in the production of forgings, especially big ones, is largely caused by forging designs. As Mr. Burton pointed out, many designs of forgings can be simplified and thereby make possible bigger production in existing forge shops. By improved design, forging time can be reduced, less time will be required to make the dies, and die life will be increased. In view of the importance of this problem, we induced O. A. Wheelon, methods analysis engineer of Douglas, to give us the article beginning on page 524. It is a "reference type" article.

WHAT'S COMING

Laws Proposed to Modify Patent Protection

Two bills are now being considered. The purpose of one is to give the President power to grant licenses to manufactur any patented product. The other bill would grant similar authority to the Commissioner of Patents. Numerous other patent rights restrictions are included in these bills, such as making it mandatory to file all the terms of a licensing agreement with the Federal Trade Commission, and making it illegal to grant licenses with any restrictions whatsoever.

October PRODUCT ENGINEERING will present a detailed analysis of these bills along with the reports of interviews with members of the Patent Committee, Commissioner of Patents, government officials, patent attorneys and industrialists.

Flash Welded Assemblies

For obvious reasons, the aircraft industry is doing a tremendous amount of experimental work on welded constructions and welding processes. Among these processes, flash welding offers many advantages, particularly in the savings of cost, weight and production time. But like all other processes, when one gets into it there are many details to consider. In a well-illustrated article with a wealth of design data, including a nomogram for figuring lengths of parts to be flash welded, L. W. Combs, research engineer of Lockheed Aircraft, covers practically all of the important factors to be considered when designing for flash welded assemblies. The article will be presented in October P.E.

What Kind of Model?

Models are handy tools but require some skill in their use. In his article to appear in October P.E., Dr. H. O. Fuchs of General Motors Corporation compares the different types of models, namely, mockups, demonstration models and models for making investigations. He explains why and when certain laws must be obeyed, when liberties may be taken, and gives examples of analogs.

The Aviation Industry is doing its job...

A Year's Production A Week — Every Week

A MERE hundred planes a month in 1938; 200 in 1939; 450 in 1940; 1,600 in 1941, and today, as this is written, plane production goes on at a rate of 5,000 a month. A previous year's production now in one single week — every week.

So begins the story of the greatest industrial expansion in history; an industrial miracle that far surpasses anything our enemies ever have done or can do. Not only did we out-produce the Axis but the acceleration in our production during the past 12 months exceeded the greatest increase in German output during their forced-draft war preparation of 1939, when their production rose from 1,100 to 1,600 planes per month.

The toughest part of our job was accomplished in 20 months. We boosted deliveries from 100 or so to 1,000 planes a week, passing the combined Axis powers. Today, Germany's curve is flattening; ours is climbing steeply. Lt. Gen. Henry H. Arnold, Chief of the Army Air Forces, assures us that Army contractors will produce not less than 148,000 planes in the remainder of 1942 and in 1943. During that same period Navy contractors will turn out at least 37,000 additional planes.

Manpower in the airframe, engine and propeller industries was increased from 125,000 to 450,000 workers during the past 20 months, with the prospect that the industry will be employing more than 1,000,000 men and women in 1943. Many manufacturers are solving their personnel problems by recruiting women workers. More than 40,000 of them — teachers, stenographers, waitresses, housewives and school girls — today are welders, assemblers, machine operators and inspectors on aircraft production lines. Productive floor space in the airframe, engine and propeller industries expanded from 18,000,000 sq. ft. to nearly 55,000,000 sq. ft. during the last 20 months. Further expansion to more than 60,000,000 sq. ft. may be expected this year and an ultimate figure of more than 100,000,000 is a distinct possibility.

To grasp the full magnitude of this task we must remember that a single medium bomber has 30,000 parts, which are built into 650 minor sub-assemblies to make 32 major sub-assemblies. The entire process involves 30,000 man hours of labor. Each of the two engines in this plane requires 50,000 specialized inspections. Every one of the 50 instruments entails many hours of precision workmanship. Yet today there is one factory turning out 4 bombers every day. Another produces fighters at the rate of nearly 20 a day.

To the amazement of the entire world these manufacturing miracles were accomplished without sacrificing the high standard of American aeronautical equipment. There has been some loose talk about the quality of our combat airplanes as compared with those of our allies and our enemies. Indisputable evidence of the superior stamina of our aircraft under fire is written between the lines of almost every war communique. Every battle record tells a story of heavy losses inflicted at small cost upon numerically superior enemy forces. The consistency of this performance on all the far-flung battlefronts constitutes the most eloquent testimony of the high calibre of our designs, our manufacturing methods and the skill and daring of our pilots.

And let us remember that our decisive victory in the battle of production was not won without headaches and heartaches on the part of management, labor and government.

When the President sounded the call for 50,000 planes in the spring of 1940, the program called for only 5,500 military aircraft. Government and industry reeled from the shock — both determined, however, that it *could and would be done.*

The Army, the Navy and the old Defense Advisory Commission set to work to draft a program. This has been revised many times — upward! Congress then proceeded, more slowly, to modify the laws that would have obstructed the realization of the objective. Then the aviation industry, without contracts, in the face of discriminatory profit-limitative legislation, and with nothing but oral assurances of governmental intentions, went ahead with its Herculean expansion plans. New factories were completed long before facilities-contracts and their funds were forthcoming.

The rugged individualists who had founded and built the aviation industry cast aside their rivalries and embarked upon a period of unselfish cooperation. Priceless engineering experience was exchanged. Material was relinquished for transfer to plants where it was needed more urgently. Successful personnel training methods and experience in the use of women workers were pooled for the benefit of all concerned. During one re-

cent month, the cooperation among eight southern California plants averted more than 1,860 potential bottlenecks in production.

As the lessons of the war dictated the need for greater numbers of particular airplane types, many manufacturers accepted orders for planes designed and developed at rival factories. Striking examples are the long range bombers being turned out by plants where only trainers, fighters or dive bombers formerly were made.

Mindful of the risk involved in educating rivals, thereby creating future potential competition, subcontractors nevertheless were sought and trained by pioneer manufacturers. Makers of toys and wheelbarrows, automatic stokers and linoleum were among those who rallied to the call. Within a year subcontracting rose from 13 to 36 per cent of the total program. It still is rising.

When the automotive industry came into the picture, aviation manufacturers gave generously of their time and knowledge to start the newcomers. Liberal licensing arrangements enabled them to reap the full benefits of technical developments. Automotive engineers swarmed through the aviation plants in search of the exacting "know-how" of the aeronautical industry.

Each type of aircraft that reaches the production stage is the result of long periods of research, design and development. The unseen workers toiling in the wind tunnels and the laboratories of government and industry are the unsung heroes who tirelessly are striving to surpass all previous efforts. Their brilliant accomplishments are eloquent testimony of the superiority of men and women who are blessed with freedom of action and thought. Today more than 20 experimental combat airplanes are under development and will replace older types as soon as they fulfill the exacting requirements of our armed forces. Among these are aircraft that promise to outfight and to out-perform any and all of the much vaunted warplanes of the Axis military machine. And this without loss of production.

Every man, woman and child of all the United Nations may fervently be thankful that those who chart our course in aircraft production have not frozen design to such a degree as to make impossible the immediate adoption of improvements as they come out of these laboratories.

What does this brilliant record mean in terms of final victory?

Every newspaper reader has learned this basic war lesson . . . air supremacy is the essential ingredient of military success. As the balance of air power shifts, so do the fortunes of war.

In those dark days when our output was 500 planes a month, Germany's was 2,000 and the German air force was twice that of our Allies. When we reached 2,000 a month last fall, Germany had advanced to a monthly rate of 2,500. Today, as this is written, we have caught up with the enemy's backlog. The air forces of both sides are about equal numerically and United Nations' production exceeds that of the Axis by 27 per cent. Next summer (1943) both the air force and the output of the United Nations will be double those of all the Axis powers.

That is the pattern of ultimate victory!

The pattern of the peace to follow also is gaining in definition. The airplane has shriveled the world to one-fifth its former size. Its use as an instrument of destruction is but a momentary distortion of the pattern of human progress. Its potential power, as a stern preserver of peace, is beyond imagination. Today's air routes of our Army Air Force Ferrying Command are the international trade routes of tomorrow. Giant airliners, by reducing time and space, will speed fraternity among the nations and disunity will give way to better understanding and goodwill.

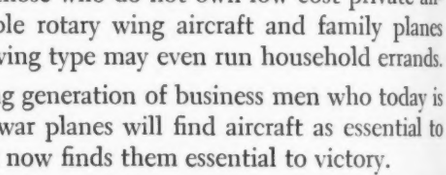
Flying freight trains, with aerial locomotives towing glider boxcars, will serve large cities, decentralizing population and giving to inland cities many of the commercial advantages of seaports. Air mail and passenger pick-up lines will fill the gaps between these transcontinental trunk lines and tie in the smallest hamlets. Universal fly-it-yourself services will provide airplane facilities for those who do not own low cost private aircraft. Roadable rotary wing aircraft and family planes of the fixed wing type may even run household errands.

The coming generation of business men who today is piloting our war planes will find aircraft as essential to business as it now finds them essential to victory.

Commenting on our war production record, Donald Nelson has said, "We are today in the position of men who realize that they are actually doing the impossible".

The mass production miracle that the aviation industry – management and workers alike – has performed through the all-out effort of free enterprise can and will serve civilization in peace as it has in war.

With this boundless new medium of transportation and its concurrent technological developments we shall rebuild our way of life to a rich, new fullness upon the ruins of a war-torn world.



President, McGraw-Hill Publishing Company, Inc.

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PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

Fighting Superiority Is All That Counts

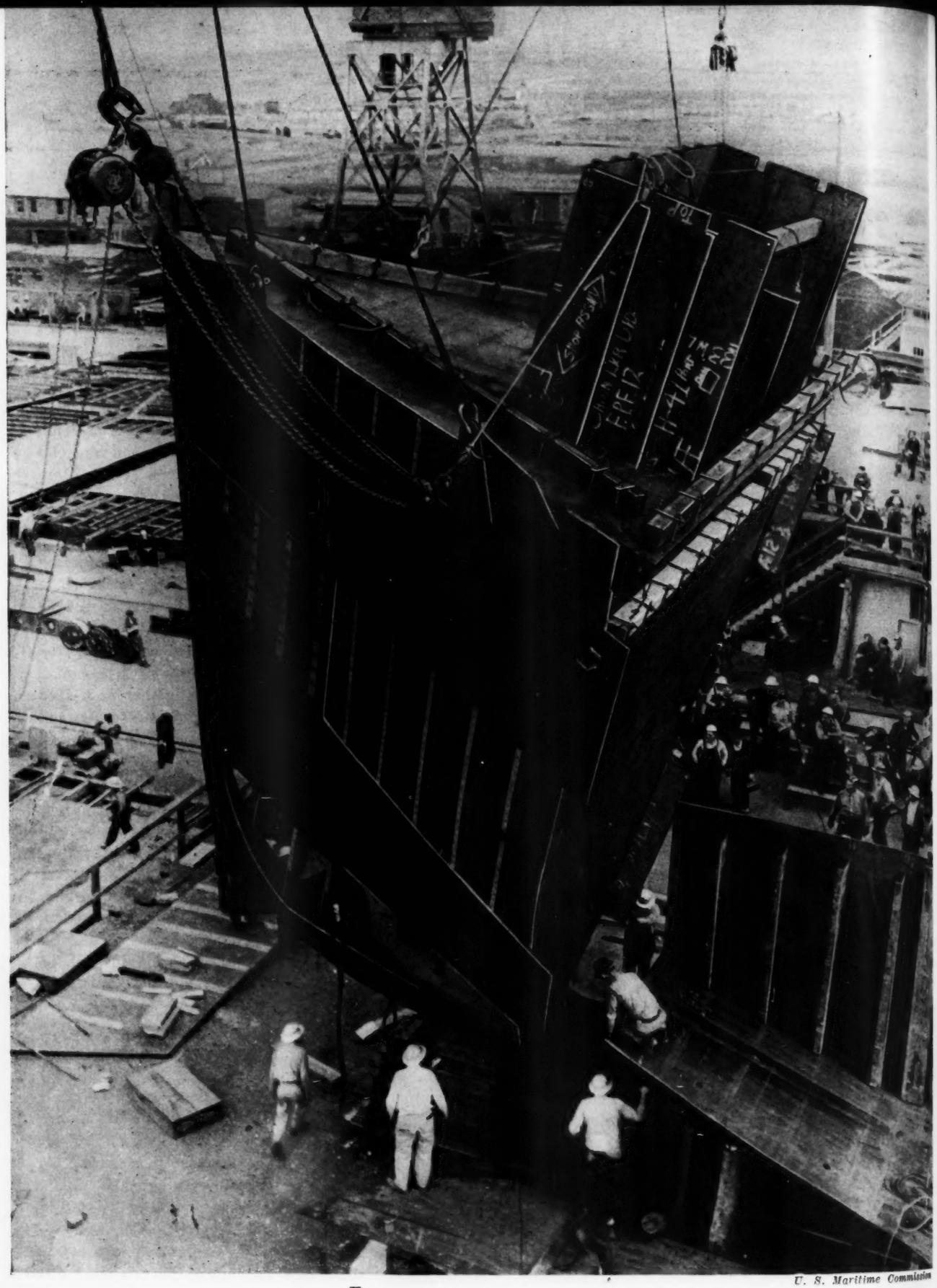
THE RELATIVE SUPERIORITY of fighting equipment is measured in battle. The decision always goes to the winning side. Excuses or explanations are futile. If the enemy has heavier guns that blast away defenses, it is absurd to argue that our own guns are better because they are lighter, hence more maneuverable. Or to claim that our smaller guns are more efficient, made of better material or have greater fire power is likewise illogical, for the only thing that counts is victory. Superiority in enemy equipment must always be clearly recognized. The design problem is then to develop equipment which, without sacrifice of other qualities, incorporates improvements over those points of enemy superiority. Better still is the development of war equipment in which new basic design principles have been applied to give the new weapon devastating superiority.

Because engineering design is largely a problem of compromising,—weighing disadvantages incurred against advantages obtained, designs that are superior to enemy equipment in every respect might seem to be beyond the range of possibility. Thus it might appear impossible to design a fighter plane as light as the Japanese Zero without sacrificing, as did the Japanese, protective armor and high structural strength. However, the solution of the problem is then to achieve the desired maneuverability not by decreasing protective armor or structural strength, but through increased horsepower, improved aerodynamic design, better structural design and other methods. The ideal solution is reached when an entirely new design concept of a fundamental character and of far reaching effects is developed and applied. Engineering of that type might be termed designing for the offensive in contrast to defensive designing, wherein the effort is primarily to equal accomplishments of the enemy.

Unfortunately, we must look to enemy equipment for the most striking examples of designs that are fundamentally new. By using compressed carbon dioxide in place of compressed air for propelling torpedoes, the Germans have virtually eliminated the tell-tale trail of bubbles in the wake of the torpedo. The carbon dioxide is almost entirely absorbed by the water before reaching the surface. Similarly, because of their heavy cast steel construction, German subs can not only resist heavier depth charges but are also able to submerge to as much as 600 feet, thereby gaining time to escape depth bombs. More recently, noteworthy ingenuity has been shown by the enemy in their design of 88 mm. anti-tank guns, the use of tungsten-carbide shell noses and similar developments.

We in America have only a few military design achievements about which to boast. We must have more. There are countless reasons why the United States should be able to develop the greatest abundance of fundamentally new and strikingly superior military designs. We have the greatest number of research scientists of outstanding ability, we have by far the greatest number of trained design engineers, we have more research laboratories and facilities than the rest of the world combined. Perhaps of greatest importance, we have an unparalleled pioneering spirit instilled in us by the founders and developers of this country.

The engineers of industry are now being called upon in ever-increasing numbers to design our weapons in cooperation with Ordnance Department and other military engineers. To develop designs which will assure victory, the engineers involved must set their sights ever higher, leaving nothing undone that might contribute to the creation of devastatingly superior fighting equipment. To this end, the best possible thought and effort, the most daring imagination, the most painstaking design analysis, the most thorough attention to the smallest details must be exercised. The quality of the job will determine life or death for thousands of our fighting men. How much better our equipment will be than that of the enemy may decide victory or defeat. Effective superiority can be attained only when the designers take the offensive, forging far ahead of the enemy's creations rather than attempting defensively to attain equality with existing enemy equipment, equipment which the foe will improve before our new designs reach the battle front. The engineers of industry who are designing our war machinery face a grave responsibility. May they always bear in mind that fighting superiority is the only thing that counts.



U. S. Maritime Commission

LIBERTY SHIP bow section being hoisted into place on the shipway is typical of the progress that has been made in the technique of prefabrication in shipbuilding. Huge units like this are completely preassembled in the shops before being carried to the ways

America's Liberty Ships
Built to Deliver Cargoes for War

How two decades of progress in shipbuilding technique and advances in American mass-production methods are made use of in the United States Maritime Commission's accelerated shipbuilding program to reduce the time and manpower necessary to fabricate material, to manufacture parts and to build hundreds of ships for World War II.

STEAMING THE HIGH SEAS on every quarter of the globe, America's mass production emergency cargo vessels are now carrying the vital necessities of war and sustenance to our overseas forces and to those of our allies. Up to the middle of this year more than 150 Liberty ships had been put into service. The first ship to go in service under the emergency program was the "Patrick Henry." She was built at the Bethlehem-Fairfield Shipyard, Baltimore, and delivered December 31, 1941. On a recent voyage to a war front the "Patrick Henry" steamed a distance of 7,633 miles at an average speed of 11.6 knots. For the greater part of the trip she carried a useful load of 11,028 long tons. After a stopover the useful load was reduced to 10,898 long tons. On this cruise the oil burned per useful load ton mile was 0.022 lb. Oil consumption was 194 barrels per day.

This performance of the "Patrick Henry" is typical of that of other Liberty ships. They are not only built in less time, they cost less to operate and are faster than the ships constructed at Hog Island some twenty odd years ago. A reasonable basis of comparison can be had by checking the performance of the "Patrick Henry" with that recorded in the logs of two ships, built at Hog Island in 1920, which are similar in type and power. On a voyage of 3,030 miles in which she carried 7,980 useful load tons, the "Artigas" averaged 9.9 knots and burned 187 barrels of oil per day, which was a consumption of 0.033 lb. of oil per useful load ton mile. The other ship, the "Cold Harbor," covered 3,201 miles with a useful load of 7,535 tons at an average speed of 10.6 knots. Her boilers took 191 barrels of oil per day, or 0.034 lb. of oil per useful load ton mile.

These records prove that the vast accelerated shipbuilding program, launched more than a year ago, with mass production methods is producing seaworthy ships that can be operated economically. Conclusively the Liberty ships are better ships. With cargo capacities greater by 1,400 to 3,500 useful load tons than their predecessors, the Liberty ships steam at a speed from one to three knots faster under comparable sea and weather conditions. As fuel-savers, they show a marked superiority.

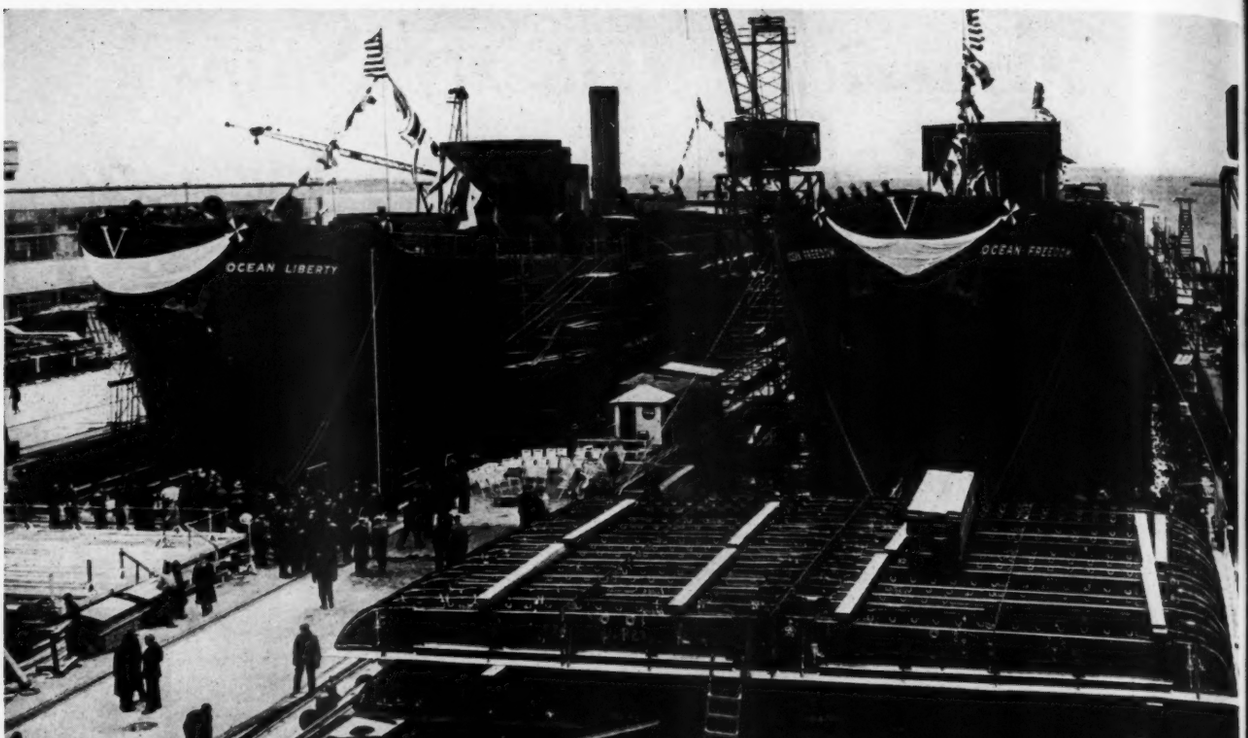
Because of the limited foundry and machine tool capacity that could be put to work for the production of steam turbines and reduction gears, as well as the comparatively long time required to build such units, the United States Maritime Commission adopted an older type of propulsion machinery for the Liberty ship. Triple expansion reciprocating engines of 2,500 hp. were chosen to propel the ships because manufacturers with adequate facilities existed in this country who could deliver the engines as fast as hulls could be built.

Chief considerations in the planning of the Liberty ship was to produce a seaworthy design that could be built rapidly at low cost, that was adaptable to mass production methods, and that also provided the maximum in cargo space and useful load carrying capacity.

The Liberty ship is of basic English design, but modifications have been introduced to facilitate construction by American speed-up production methods. Of the single screw type, with raked stem and cruiser stern, the hull is subdivided by seven main bulkheads to provide five cargo holds. The Liberty ship (Design EC-2) has an overall length of 441 ft. 6 in.; a beam of 57 ft., a depth of 37 ft. 4 in., a total displacement of 14,100 tons and a general cargo capacity of 9,146 tons. Boilers, engines, fuel and fuel tanks, auxiliaries, cargo gear, water, stores and fittings account

Fig. 1—Tank being loaded aboard a Liberty ship destined for a distant battlefront

U. S. Maritime Commission



U. S. Maritime Commission

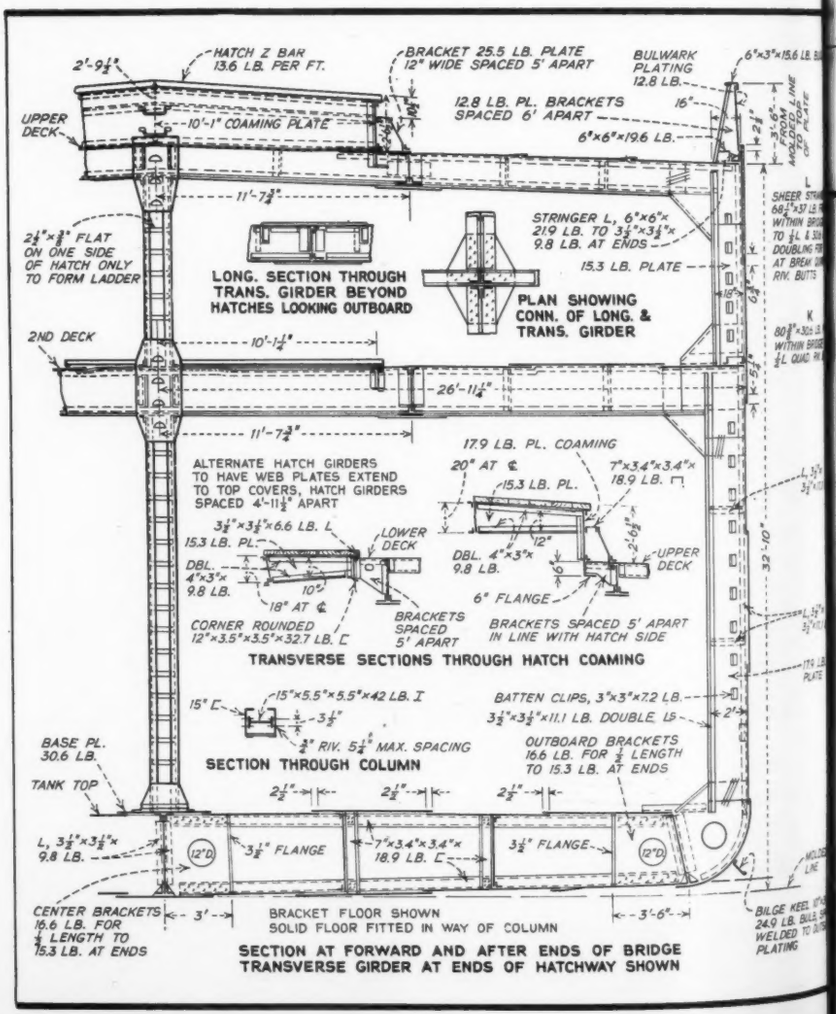
Fig. 2—Two Liberty ships as they appeared on launching day. In the foreground can be seen prefabricated parts for the hulls that will be built in the berths vacated by these two vessels

for 1,529 tons. A total of 3,425 tons of steel are used in the construction of the hull, decks and deck structures. Of this 2,725 tons are in the form of plates and 700 tons are shapes.

The building and construction of the yards to produce Liberty ships was an amazing feat. None of the yards in which these vessels are being built was in existence a year ago. These new yards especially created for this great task are the product of men experienced in shipbuilding who have the vision to make effective use of modern mass production methods and intensive training systems to make available a supply of men who can build ships. The key men in the new shipyard organizations were drafted from existing shipyard staffs.

Distribution of Work

All the Liberty ships are built in accordance with one set of lines, dimensions and specifications as furnished by the United States Maritime Commission. Each contractor, however, can arrange many details of fabrication and assembly to suit his available facilities, subject of course to the approval of the Commission. Specifications have been simplified in order to save time and to eliminate, as far as possible, the use of materials which are highly essential for


HATCH Z BAR 13.6 LB. PER FT.
BRACKET 25.5 LB. PLATE 12" WIDE SPACED 5' APART
BULWARK PLATING 12.8 LB.
12.8 LB. PL. BRACKETS SPACED 6' APART
6"×6"×19.6 LB.
UPPER DECK
10'-1" COAMING PLATE
11'-7⅜"
2¼"×⅜" FLAT ON ONE SIDE OF HATCH ONLY TO FORM LADDER
LONG. SECTION THROUGH TRANS. GIRDER BEYOND HATCHES LOOKING OUTBOARD
STRINGER L, 6"×6"× 21.9 LB. TO 3½"×3½"× 9.8 LB. AT ENDS
15.3 LB. PLATE
PLAN SHOWING CONN. OF LONG. & TRANS. GIRDER
2ND DECK
10'-1½"
26'-11¼"
11'-7⅜"
ALTERNATE HATCH GIRDERS TO HAVE WEB PLATES EXTEND TO TOP COVERS, HATCH GIRDERS SPACED 4'-11½" APART
17.9 LB. PL. COAMING
20" AT ℄
7"×3.4"×3.4"× 18.9 LB. ⊏
15.3 LB. PL.
3½"×3½"×6.6 LB. L
15.3 LB. PL.
LOWER DECK
DBL. 4"×3"× 9.8 LB.
12"
DBL. 4"×3"× 9.8 LB.
UPPER DECK
6" FLANGE
18" AT ℄
CORNER ROUNDED 12"×3.5"×32.7 LB. ⊏
BRACKETS SPACED 5' APART
BRACKETS SPACED 5' APART IN LINE WITH HATCH SIDE
TRANSVERSE SECTIONS THROUGH HATCH COAMING
15"×5.5"×5.5"×42 LB. I
BATTEN CLIPS, 3"×3"×7.2 LB.
3½"×3½"×11.1 LB. DOUBLE L5
⅜" RIV. 5½" MAX. SPACING
SECTION THROUGH COLUMN
OUTBOARD BRACKETS 16.6 LB. FOR ¼ LENGTH TO 15.3 LB. AT ENDS
BASE PL. 30.6 LB.
TANK TOP
L, 3½"×3½"× 9.8 LB.
3½" FLANGE
7"×3.4"×3.4"× 18.9 LB. ⊏
3½" FLANGE
CENTER BRACKETS 16.6 LB. FOR ¼ LENGTH TO 15.3 LB. AT ENDS
BRACKET FLOOR SHOWN SOLID FLOOR FITTED IN WAY OF COLUMN
SECTION AT FORWARD AND AFTER ENDS OF BRIDGE TRANSVERSE GIRDER AT ENDS OF HATCHWAY SHOWN

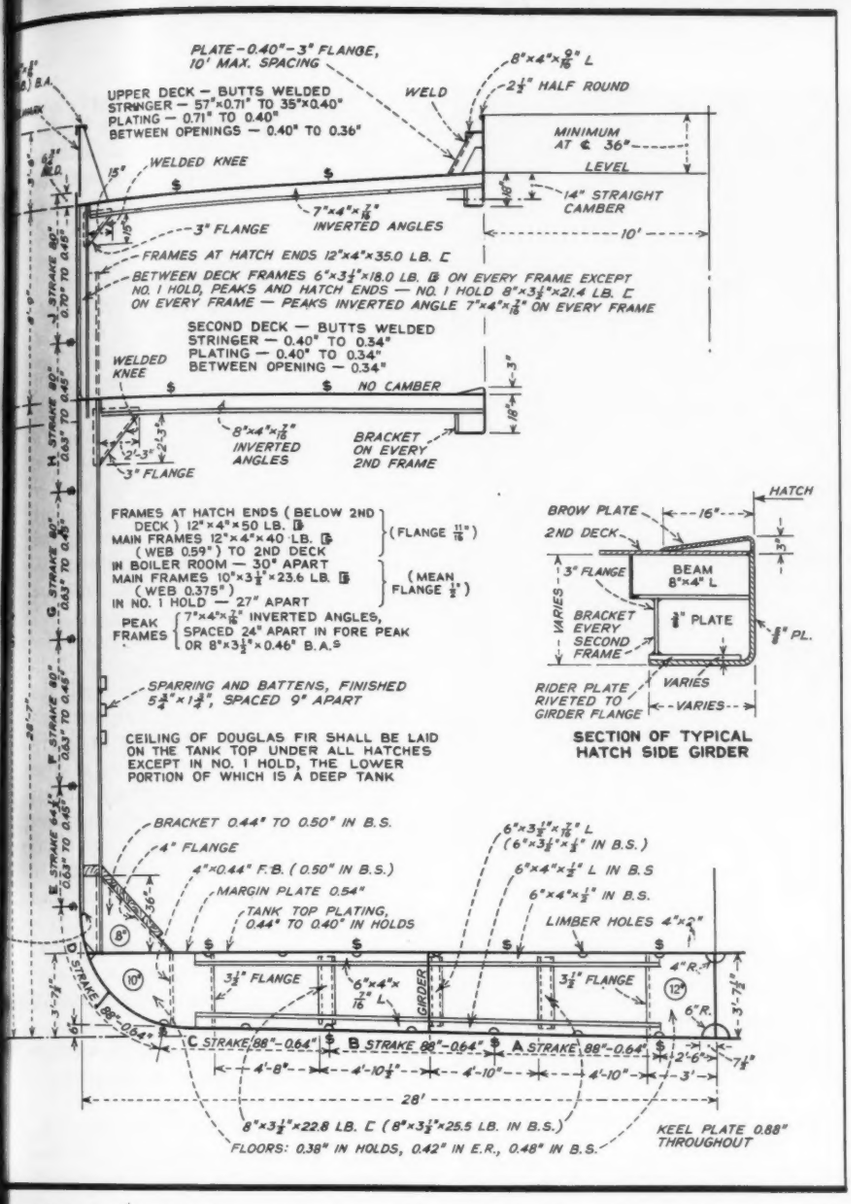


PLATE-0.40"-3" FLANGE, 10' MAX. SPACING
UPPER DECK — BUTTS WELDED
STRINGER — 57"×0.71" TO 35"×0.40"
PLATING — 0.71" TO 0.40"
BETWEEN OPENINGS — 0.40" TO 0.36"
WELD
8"×4"×9/16" L
2½" HALF ROUND
MINIMUM AT ℄ 36" LEVEL
14" STRAIGHT CAMBER
10'
WELDED KNEE
3" FLANGE
7"×4"×7/16" INVERTED ANGLES
FRAMES AT HATCH ENDS 12"×4"×35.0 LB. C
BETWEEN DECK FRAMES 6"×3½"×18.0 LB. B ON EVERY FRAME EXCEPT NO. 1 HOLD, PEAKS AND HATCH ENDS — NO. 1 HOLD 8"×3½"×21.4 LB. C
ON EVERY FRAME — PEAKS INVERTED ANGLE 7"×4"×7/16" ON EVERY FRAME
SECOND DECK — BUTTS WELDED
STRINGER — 0.40" TO 0.34"
PLATING — 0.40" TO 0.34"
BETWEEN OPENING — 0.34"
NO CAMBER
8"×4"×7/16" INVERTED ANGLES
BRACKET ON EVERY 2ND FRAME
FRAMES AT HATCH ENDS (BELOW 2ND DECK) 12"×4"×50 LB. B
MAIN FRAMES 12"×4"×40 LB. B (WEB 0.59") TO 2ND DECK
IN BOILER ROOM — 30" APART
MAIN FRAMES 10"×3½"×23.6 LB. B (WEB 0.375") IN NO. 1 HOLD — 27" APART
(FLANGE 11/16")
(MEAN FLANGE ½")
PEAK FRAMES 7"×4"×7/16" INVERTED ANGLES, SPACED 24" APART IN FORE PEAK OR 8"×3½"×0.46" B.A.S
SPARRING AND BATTENS, FINISHED 5¼"×1¾", SPACED 9" APART
CEILING OF DOUGLAS FIR SHALL BE LAID ON THE TANK TOP UNDER ALL HATCHES EXCEPT IN NO. 1 HOLD, THE LOWER PORTION OF WHICH IS A DEEP TANK
BROW PLATE
2ND DECK
HATCH
16"
3" FLANGE
BEAM 8"×4" L
VARIES
BRACKET EVERY SECOND FRAME
1" PLATE
1" PL.
RIDER PLATE RIVETED TO GIRDER FLANGE
VARIES
SECTION OF TYPICAL HATCH SIDE GIRDER
BRACKET 0.44" TO 0.50" IN B.S.
4" FLANGE
4"×0.44" F.B. (0.50" IN B.S.)
MARGIN PLATE 0.54"
TANK TOP PLATING, 0.44" TO 0.40" IN HOLDS
6"×3½"×7/16" L (6"×3½"×½" IN B.S.)
6"×4"×½" L IN B.S.
6"×4"×½" IN B.S.
LIMBER HOLES 4"×2"
3½" FLANGE
6"×4"×7/16" L
GIRDER
4" R.
6" R.
C STRAKE .88"-.64"
B STRAKE .88"-.64"
A STRAKE .88"-.64"
4'-8"
4'-10½"
4'-10"
4'-10"
3'
2'-6"
7½"
28'
8"×3½"×22.8 LB. C (8"×3½"×25.5 LB. IN B.S.)
FLOORS: 0.38" IN HOLDS, 0.42" IN E.R., 0.48" IN B.S.
KEEL PLATE 0.88" THROUGHOUT

Fig. 3 (Left)—Midship section of a 9,000 ton deadweight freighter built about 1920. Note riveted construction which necessitated the use of boundary angles and clips for fastenings and joints

Fig. 4 (Above)—Midship section of Liberty ship. Cargo capacity is 9,146 tons. Note simplicity of structure that welding makes possible

the manufacture of other strategic products needed in the war economy.

The Liberty ship program is a mass production project involving the manufacture of thousands of items that go into each ship. This work is spread through more than 500 manufacturing plants, great and small, throughout the nation. Parts and subassemblies from these factories are transported to the yards for final assembly and installation in the ship structures. This method of distributing the work involves many obvious time saving factors. As more and more subassembly units are fabricated throughout the country the operations performed in the shipyard become more than ever only those which are concerned with final assembly. Every fabricated unit subassembly for the ship structure is made to suit the contour and dimensions of a template or mold board. Through the use of this system it is assured that mating edges of adjoining subassemblies will fit each other for fastening operations.

During and immediately following World War I the conventional way of fastening parts of a ship together was by riveting. This system, except for lap and butt joints, demanded the use of boundary angles and flanges at the edges of web plates; and also channels, angles and angle clips for intermediate stiffeners. The use of such rolled shapes simply as a means for providing edges and surfaces that could be fastened together added considerably to the built-in weight of the ship. In addition to this each rivet head and the larger sizes of plate, that had to be used in order to maintain sufficient net areas at sections that were punched or drilled for rivets, subtracted from the useful cargo load that a ship might otherwise carry.

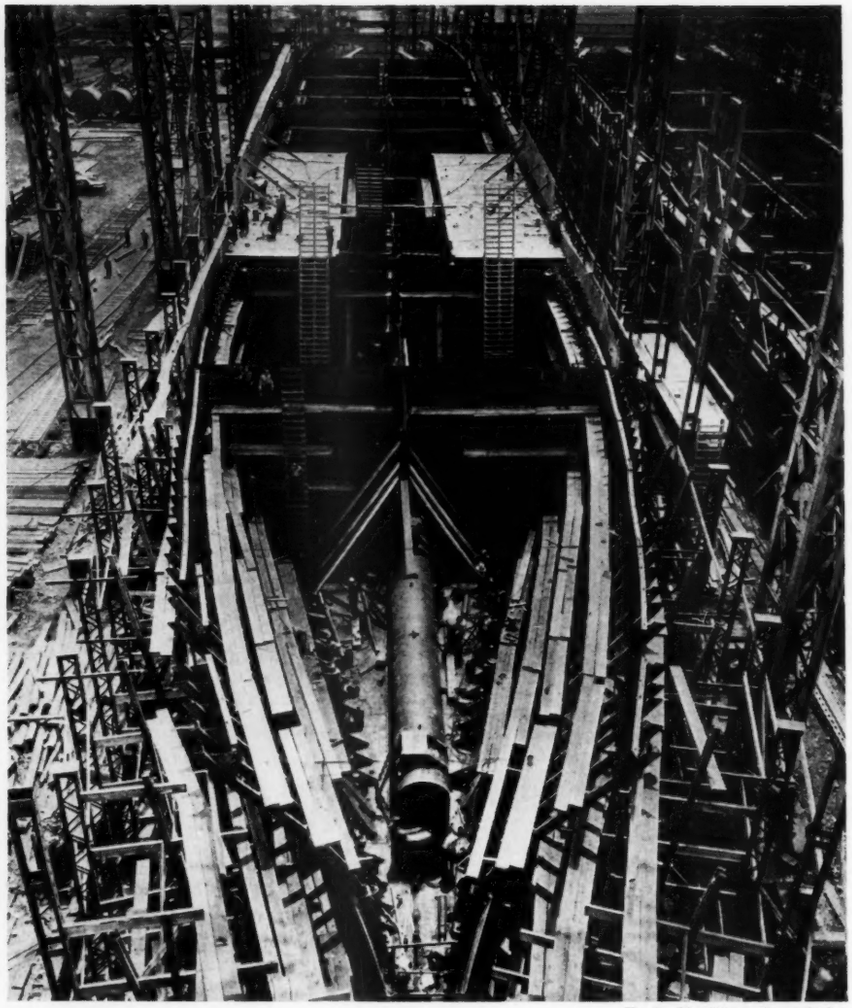
Time, manpower and useful load carrying capacity are being saved now in the shipyards by welding steel sheets and rolled shapes together instead of riveting. The ships built in America today are 85 percent welded. Most yards are welding all seams. All shell strake joints are lap welded; vertical seams are butt welded.

Welded Construction

In welded ship construction there is a more appreciable loss of dimension than that encountered in riveted construction. When parts are riveted together there is a tendency for creep to accumulate that makes for a gain in dimension. Welding, however, tends to draw the parts together. In butt joints this is caused by the shrinkage of the filler metal which, of course, is applied in the molten state. When welding continuous or passing members such as is done in joining the framing to the shell plating, there is a shrinkage in the zone of the weld which in turn shortens the passing member. The welded hull of the ship will therefore be less than its molded length unless measures are taken to counteract or compensate for this loss of dimension. There are too many still unknown factors in the problems of shrinkage control that prevent the welding operator or shipbuilder from setting up a valid rule for the prediction of shrinkage. Experienced fabricators add an arbitrary allowance to the length and width of parts that are subject to welding shrinkage. Accumulation of any excess is corrected in the course of construction.

In shipbuilding, however, the matter of loss of dimension is not in itself a major consideration, apart from the fact that there is a difference in the capacity as designed and as actually displaced. The difference in speed and power is so slight as to be practically negligible.

The problem of distortion that makes itself evident in wrinkles or bulges in flat plates and those with small curvature constantly faces the shipbuilder. While the presence of slight hollows and bumps on a ship's hull in no way detracts from the strength of the structure, they are eyesores and sometimes make the attachment of the distorted



U. S. Maritime Commission

Fig. 5—View of Liberty ship under construction at an East Coast shipyard

part to other parts difficult. Many warped parts are straightened by hammering after heating.

Many methods have been resorted to by shipbuilders to prevent distortion of parts in welded structures. Parts are sometimes set or bent in a direction that will offset an expected warping in welding. Temporary stiffening members may be used to hold the part or subassembly in alignment during welding and cooling. If the edges of large thin plates can be welded to structures or frames that offer considerable resistance to yelding, a drum-heading method can be followed to introduce a boundary restraint, so that when shrinking occurs the plate will remain flat. By means of a wandering sequence in welding in which all joints are completed at the same time, as opposed to the completion of a frame by frame method, distortion may be considerably reduced because of the number of restraints and also because the welded areas do not distribute heat over as great an area as would result if each joint were welded at one operation.

Another method sometimes used to correct buckling of flat areas in the welded structure is to run beads of weld metal on the convex side of the distorted area. The heat applied to the area in the bead welding operation increases the ductility of the steel member so that as both the bead and the plate cool the resultant shrinkage corrects the distortion.

Residual Stresses

Certain of these preventive measures, notably drum-heading, extensive tacking, and the wandering sequence as well as the corrective methods of torch shrinking and shrink welding, as noted in the report of a Subcommittee of the Committee on Welding in Marine Construction of the American Welding Society. (*Welding Journal*, September, 1941), are directly opposed to the theory that the structure should be free of residual stresses. The report further notes that the success of these measures is probably because opposed and equal stresses are set up. Taken rather broadly, structures tend to relieve themselves by distortion. In many instances it follows that its prevention, or correction, means the creation of residual stresses.

The satisfactory behavior of welded structures in service, of course, is predicated upon sound welds. The obtaining of sound and properly fused welds, free of checks and incipient cracks, as well as slag, porosity, blowholes and the like, is therefore of major importance. To this end procedure includes much more than sequence of welding, in fact, other factors such as preheat, the continuity of the welding operation, peening and an endeavor to assure a uniform distribution of stress over the joint are often of equal importance.

Almost all welded structures for ships, because of their large overall dimensions, must be put in service in the as-welded condition. Test reports indicate that shrinkage stresses in the vicinity of welded joints set up a stress distribution in and near the joint that is exceedingly complicated and indeterminate. Because of the nature of the operation high residual stresses can be expected irrespective of any external restraint.

Residual stresses also make up an internal force system that must obviously be in equilibrium. When external loads are applied there is no simple addition to like forces from which to conclude that some local point may be overstressed.

An additional factor that should be considered in a discussion of residual stresses in welded ship structures is the relatively high ductility of the steels used. Although the yield point of the material may be reached in slight extensions, the load is re-distributed to the surrounding material before local points elongate appreciably in the highly stressed zone.

It is practically impossible in shipbuilding to porform all welding operations in a theoretically perfect sequence. There are numerous final joints that can be made only after other sections have been completed. With this condition present, of course, the final joint does not have much opportunity to shrink. The successful performance record and seaworthiness of ships that have been assembled by welding during the last decade proves conclusively that such structures do not depend upon the elimination of residual stresses to resist the loads they are subjected to in service, but upon the ability of the materials used in construction to accommodate a wide distribution of internal stresses at critical areas.

Computing Distances for Shop Photos

A. C. RASMUSSEN

OFTENTIMES the engineer uses a camera to keep a record of the appearance of a piece of machinery or the progress in the construction of a structure. In taking the picture it is desirable to cover as much of the film or plate as possible with details that will be of the maximum value as a record. To do this, the photographer steps back an indefinite distance from the object and determines the correctness of his position by looking through the finder or at the ground glass. Naturally, if he is using a camera with a ground glass, there is no difficulty in getting full coverage on the negative, leaving a proper margin. But with a camera having only a view finder, there is not the certainty of maximum coverage.

With an object of known width or height, the question often occurs as to whether a desirable picture can be taken from a certain point. This may be from against a wall for a piece of machinery inside a building, or from the top of a tool shack or some other point of vantage on a construction job.

Theory of the photographic lens for a problem such as this is quite simple. For a camera having a lens of a given focal length and using plates or films of a certain size, a table can be worked up, showing for objects of different widths or heights the distances at which full coverage can be obtained on the negative.

Fundamental applicable formulas are

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \qquad (1)$$

and

$$M=\frac{v}{u} \qquad (2)$$

in which, measured in the same units,

u = distance from lens to object, minimum range

v = distance from lens to image.

f = focal length of lens

M = magnification (less than unity).

Also, let S = length or height of object and

L = dimension of negative taken parallel to length or height of object

Rewriting Equation (1)

$$\frac{v}{u}=\frac{f}{u-f} \qquad (3)$$

Combining Equations (2) and (3)

$$\frac{L}{S}=\frac{f}{u-f} \qquad (4)$$

from which,

$$u=f+\left(\frac{f}{L}\right)S \qquad (5)$$

Table I—Minimum Camera Ranges

For 3¼ x 5½ in. camera having a lens of 6¾ in. focal length

S Width or height of object, ft.	u_1 for film width, range in ft.	u for film length, range in ft.
2¾		6
3¼		7½
4		9
5	6¾	11
6	8	13
8	10½	17½
10	13	21½
12½	16	27
15	19	32
20	25	42
25	32	53
30	38	63
45	44	74
40	50	84
50	62	105
60	75	126
80	100	167
100	125	210

Knowing the focal length of the lens, which is usually engraved either on the retainer ring of the front element or on the lens barrel, and the length and width of the negative used, it is a simple matter to develop a table showing the minimum distance at which to stand away from an object in terms of the width or height of the object. Actually, two tables are necessary, one for pictures taken across the long way of the negative and one for pictures across the short way.

Assume that one has a 3¼ by 5½ in. camera with a lens of 6¾ in. focal length. Substituting values in Equation (5) in which L equals 5½ in. and expressing all dimensions in ft., then

$$u=\frac{6.75}{12}+\left(\frac{6.75}{5.5}\right)S \qquad (6)$$

or

$$u=0.56+1.23\,S \qquad (7)$$

If an object is 10 ft. wide and the picture is taken the long way of the negative, then

$$u=0.56+1.23\times 10=12.86 \text{ or } 13 \text{ ft.}$$

For an object width of 80 ft. and with the picture still taken the long way of the negative, then for practical purposes,

$$u=0.56+1.23\times 80=98.96 \text{ ft.,}$$

99 or 100 ft.

In the first case, the photographer must stand not less than 13 ft. away to get full coverage and in the second case not less than 100 ft. away.

One should stand 15 to 25 percent farther away if a proper margin is desired around the object on the print.

For the shorter way of the 3¼ by 5½-in. negative, the substitutions in Equation (5) are:

$$u_1=\frac{6.75}{12}+\left(\frac{6.75}{3.25}\right)S \qquad (8)$$

or

$$u_1=0.56+2.08\,S \qquad (9)$$

Then for the 10-ft. object,

$$u_1=0.56+2.08\times 10=21.36, \text{ or } 21\tfrac{1}{2} \text{ ft.}$$

practically.

For the 80-ft. object, for practical purposes,

$$u_1=0.56+2.08\times 80=166.96 \text{ or } 167 \text{ ft.}$$

Some lenses have a focal length expressed in millimeters and the small candid cameras use film measured in millimeters. However, the user still thinks of distances in feet. As there are 25.4 millimeters to an inch and therefore 304.8 millimeters to a foot, the formula is written:

$$u=\frac{f}{304.8}+\frac{f}{L}\times S \qquad (10)$$

For practical purposes,

$$u=0.0033\,f+\frac{f}{L}\times S \qquad (11)$$

Substitutions of values are made as before.

Note that these values indicate only the minimum distances to stand away from the object. It is still necessary to focus the camera.

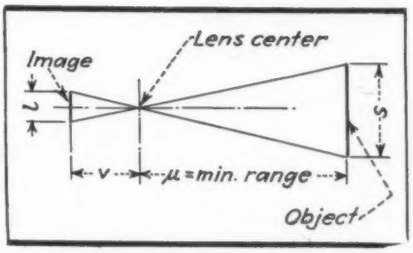


Fig. 1—Factors that determine size of photographic image on negative

A complete table has been worked up for a 3¼ by 5½-in. camera with lens of 6¾-in. focal length. With this, the bellows is fully extended at 6 ft. focusing distance, and therefore the table starts with 6 ft. as a minimum distance.

Thermal Insulating Materials for Industrial Equipment

S. V. SAGINOR
Davey Compressor Company

Discussion of numerous factors that should be considered when selecting, specifying and installing insulating materials for industrial equipment which depend upon the control of temperature over narrow ranges for efficient operation. Characteristics of various insulants are included.

INSULATION MATERIALS, either for the purpose of preventing the escape of heat or for preventing the absorption of heat in order to maintain desirable temperature conditions in industrial equipment, to be effective must be selected only after a thorough consideration of the design requirements and a study of anticipated performance. As shown in Table I there are many types of insulants, each one has characteristics peculiar to itself. In choosing both the type and thickness of insulation the engineer should be guided by the economic aspect, comfort requirements and process temperature.

Normal depreciation and obsolescence of equipment should be considered in determining the economic value of insulation for the operation involved, type of equipment and its location. When frequent replacement of gaskets are necessary which require the removal and replacement of a portion of the insulation it may be economical to design a portion of the insulation to facilitate such maintenance work.

The design engineer must check for clearances required for the application of the selected type and thickness of insulation. It is also important to determine, if possible, the amount of abuse to which the insulant will be subjected from vibration and exposure to moisture.

With the exception of reflective metals, an efficient insulant should structurally consist of numerous air cells, microscopically small, so that heat circulation within and radiation across them are of small magnitude.

To be effective at refrigeration temperatures, with their attendant condensation effects, the insulant should be resistant to moisture vapor penetration or be protected by an asphalt coating, asphalt impregnated membrane or some suitable vapor barrier, since moisture absorption will quickly reduce the original efficiency of the insulant. Although no insulant can in itself be considered absolutely vapor-proof, satisfactory asphalt or oil impregnated mineral wools are available for low temperatures that do not require supplementary sealing. Also, there has recently been developed for cold water insulation a vapor barrier consisting of cotton sheeting sprayed with liquid latex.

Electric resistivity is also a factor requiring consideration if the insulant is used in connection with induction heating equipment.

Inflammability of insulants, finishes and accessories should be determined, particularly where used in fire hazard zones. Often double layer construction is desirable purely to avoid the possibility of auto-ignition of the outer covering where leakage of heat occurs through cracks or improperly sealed joints.

Care must be taken to ascertain strength in the particular temperature range at which the insulant is to be used. Fig. 1 shows how crushing strength can vary with temperature.

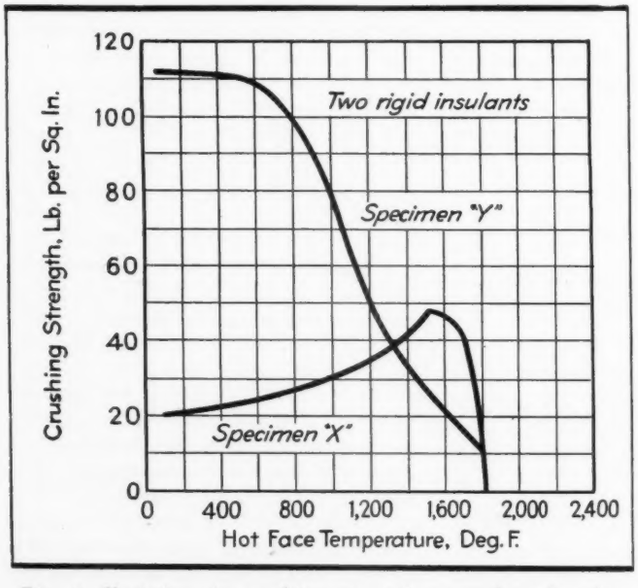


Fig. 1—Variation in crushing strength at various hot face temperatures for two rigid insulants

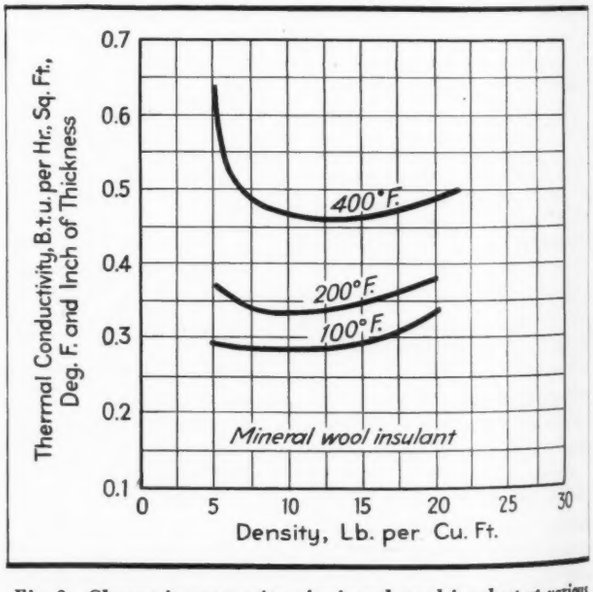


Fig. 2—Change in properties of mineral wool insulant at various temperatures and densities

Table I—Some Physical and Thermal Characteristics of Commercial Insulants

Material	Commercial Forms Available	Upper Limiting Temp., Deg. F.	Density, Lb. per Cu. Ft.	Thermal Conductivity, B.t.u. per Hr., Sq. Ft. Deg. F. and In. Thickness at Mean Temperature, Deg. F.									
				100	200	300	400	500	600	800	1,000	1,200	1,500
Aluminum Foil	Built-up sectional and block	1,000	0.2	0.28	0.37	0.39	0.46	0.52	0.58				
Asbestos	Loose fibre	800	36	0.16	1.23	1.40	1.45	1.48	1.50	1.56			
Asbestos Finishing Cements	Loose dry	1,000	48–60		1.50								
Asbestos Air Cell	Sectional and block												
	4 plies per in.	300	12	0.53	0.65	0.77	0.89						
	8 plies per in.	300	19	0.48	0.56	0.63	0.71						
Asbestos Felts (sponge felt)	Sectional and block												
	40 laminations per in.	700	30	0.40	0.44	0.49	0.53	0.59					
	20 laminations per in.	700	20	0.55	0.61	0.67	0.73	0.79					
Asbestos Millboard	Sheets	1,000	54	0.90	0.95	1.00	1.20	1.40	1.50				
Asbestos Sprayed	Loose fibre and liquid binder	800	7	0.36	0.41	0.46	0.53	0.63					
Concrete—Insulating Type	Loose granular	1,800	31	1.72	1.80	1.87	1.94	2.01	2.08	2.23	2.37	2.51	2.73
Concrete—Insulating Refr'y	Powder	2,200	65			2.78	2.82	2.86	2.90	2.98	3.09	3.20	3.44
Cork	Sectional and block	200	11	0.30									
Diatomaceous Earth	Fine Powder	1,600	15–17	0.38	0.41	0.44	0.48	0.51	0.55	0.62	0.69	0.76	0.86
	Coarse powder	1,600	22	0.45	0.48	0.52	0.55	0.59	0.62	0.70	0.77	0.84	0.95
High Temp. Alumina and Diatomac. Silica Mixtures	Sectional and block	1,900–2,000	24–30		0.59	0.61	0.64	0.68	0.70	0.76	0.82	0.88	
Hair Felt	Blanket	200	13	0.30									
Silica Brick	Brick	3,100–3,300	130–150	6.20	6.50	6.80	7.00	7.30	7.60	8.20	8.80	9.40	10.20
Firebrick	Brick	2,250–3,200	110–112	5.80	6.00	6.20	6.50	6.70	6.90	7.40	7.80	8.30	9.00
Red Brick	Brick	500–1,000	100–120	4.50	4.70	5.00	5.20	5.50	5.80	6.30	6.80	7.30	8.10
Insulating Brick	Brick	2,500	39–53		1.57	1.73	1.84	2.01	2.14	2.50	2.53	2.83	
Insulating Brick	Brick	2,000	28–38		1.12	1.15	1.19	1.23	1.27	1.37	1.48	1.62	
Insulating Brick	Brick	1,600	30		0.78	0.81	0.85	0.89	0.93	1.00	1.09	1.16	
Kapok	Blanket	212	1	0.25									
Magnesia—85%	Sectional and block	600	17	0.43	0.47	0.51	0.55						
Magnesia Cements	Loose dry	600	21	0.48	0.54	0.60	0.66						
*Mineral Wools (untreated)													
Glass Wool	Loose, flexible	1,000	3	0.26	0.32	0.41	0.61						
	Sectional and blanket		4	0.24	0.30	0.38	0.52						
			8	0.22	0.26	0.30	0.36						
Rock Wool	Loose, flexible		5	0.29	0.37	0.47	0.64						
			10	0.28	0.33	0.39	0.46						
	Sectional and blanket	1,000	15	0.29	0.35	0.40	0.47						
			20	0.34	0.38	0.43	0.49						
Slag Wool	Loose, flexible												
	Sectional and blanket	1,000	Generally same as Rock Wool										
Mineral Wool Type Cements	Loose dry	1,500	24–30	0.57	0.61	0.66	0.77	0.88	1.02	1.15	1.44		
Mineral Wool (waterproofed low-temperature type)	Board	225	18	0.36									
	Sectional and block	165	15	0.30									
	Blanket	225	16	0.29									
Vermiculite	Sectional; Block	1,600	17	0.57	0.64	0.69	0.73	0.76	0.80	0.89	0.98		
	Loose	1,600	8	0.52									
Vermiculite Type Cements	Loose dry	1,800	16	0.74	0.79	0.84	0.89	0.94	1.04	1.14	1.25		
Wool Felt	Sectional or block	212	24	0.36									

Note: Conductivity figures represent average value of commercial makes of various manufacture. Conductivity of cements, loose fills and flexible insulants varies with applied density.

* Some manufacturers recommend 1,200 deg. F. limit for mineral wools.

* Glass wool also available in special board form with limiting temperature of 1,600 deg. F.

Material may attain higher insulating values at high temperatures, as shown in Fig. 2, but they may lose so in structural strength that slight vibration or abrasion may cause rapid disintegration.

Chemical reaction of insulants on various metals should be determined. Account must be taken of plant atmospheric conditions and exposure of the insulant to other possible abuse such as might result from weatherproofing failure.

The importance of thickness and weight after application also justifies investigation because of possible changes in the insulant under service conditions, with moisture absorption, dehydration, or possible deterioration. Also the variation in conductivity and in weight for layers having different applied densities of flexible or loose insulant should be considered as to the effect on the anticipated result.

Where fibrous or granular materials are used, the possibility of settling because of vibration should be considered. This may be avoided by the inclusion of binders or by the use of denser material or by building in mechanical aids such as regularly spaced supports. Consideration should be given to the use of intermediate supports on suspended equipment to relieve the insulant of a part of its own weight.

Insulating cements may be satisfactory from a thermal efficiency standpoint, but shrinkage, insufficient adhesiveness, low covering capacity, and drying out time may rule out their use as primary insulants. It is usually unsatisfactory to apply cement types in layers greater than 1 in. and, of course,

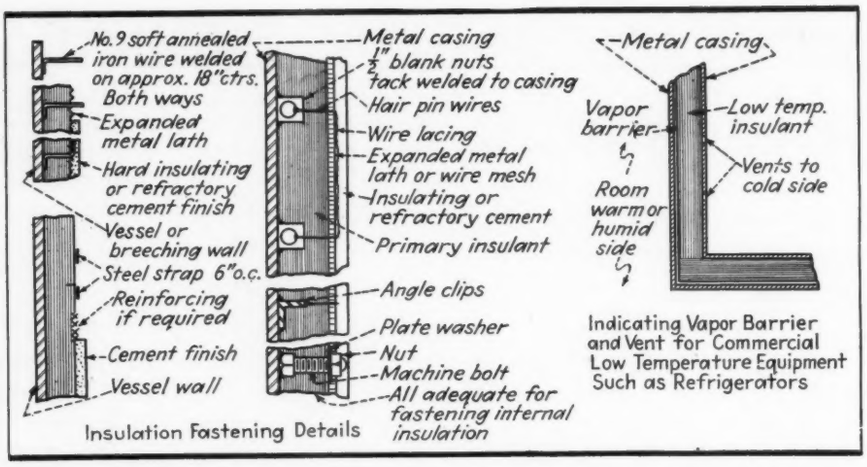

No. 9 soft annealed iron wire welded on approx. 18" ctrs. Both ways
Expanded metal lath
Hard insulating or refractory cement finish
Vessel or breeching wall
Steel strap 6" o.c.
Reinforcing if required
Cement finish
Vessel wall
Metal casing
1" blank nuts tack welded to casing
Hair pin wires
Wire lacing
Expanded metal lath or wire mesh
Insulating or refractory cement
Primary insulant
Angle clips
Plate washer
Nut
Machine bolt
All adequate for fastening internal insulation
Insulation Fastening Details
Metal casing
Vapor barrier
Low temp. insulant
Vents to cold side
Room warm or humid side
Indicating Vapor Barrier and Vent for Commercial Low Temperature Equipment Such as Refrigerators

Fig. 3—Insulation fastening details for vessels, breeching walls and metal casings

each layer should dry thoroughly before the application of a succeeding layer in order to insure a good bond.

Materials for Various Temperature Ranges

Vegetable cork is used extensively in granular, sectional and hard board form, below 40 deg. F. in the low temperature or industrial refrigeration range. Cattle hair, although it requires careful sealing, has also been used successfully. The mineral wool industry contributes a material, which, when properly processed and treated with special oils for the flexible forms or with asphalt to produce board and sectional forms, is highly effective down to the lowest industrial range.

Kapok and fibrated wood products are available for low temperatures. Sponge or expanded rubber is also adaptable for the moderately low range. Kapok is an excellent insulant for transportation equipment, providing light weight, durability, moisture resistance, and lack of odor absorption. This material may be obtained in flexible blankets and in pliable slab form.

Wool felt consisting of paper or rag stock in laminated form cemented together with sodium silicate, has given excellent results as an insulant for hot and cold water service in the range of 40 to 200 deg. F. This material is available in indented, pre-shrunk form, with improved thermal efficiency and offers a reasonably priced installation.

Corrugated asbestos paper layers cemented together with sodium silicate into block form is a serviceable air cell type of insulation for the medium temperature range, from 100 to 300 deg. F., except where liability to mechanical damage or high atmospheric humidity prevail. Pre-shrinking of this material is a recent improvement which reduces the disadvantage of shrinking in service to a minor factor. Also available is an indented form of air cell which gives slightly higher insulating efficiency with an increased number of paper layers.

Magnesia consisting of 85 percent magnesium carbonate mixed with 15 percent of asbestos fibre, is a molded composition of good insulating efficiency for the range from 220 to 600 deg. F. This material has considerable mechanical strength.

Laminated asbestos insulation, made by cementing together layers of asbestos felts with narrow bands of sodium silicate, offers a highly efficient insulant known as sponge felt. With a limiting temperature of 700 deg. F., it is particularly suitable for conditions of abuse or excessive vibration, but it has the disadvantage of high weight. An improved type of sponge insulant consisting of indented felts containing imbedded particles of sponge, is also available.

An aerated diatomaceous silica asbestos cement mixture is a new substance made in sheet form and is of particular interest. It may be used alone in rigid sheet form or faced on one or both sides with asbestos cement sheets, as part of the fabricated wall, or as the entire wall construction of many types of equipment. Originally developed for marine fireproofing, this material has a temperature limit of 700 deg. F. for some grades and up to 1,500 deg. F. for others.

Mineral wool insulations are produced in blanket form, with or without metal reinforcing, for a wide range up to 1,200 deg. F. This group of insulants consists of slag wools, rock wools, and glass wools. In this same temperature range, aluminum foil and other highly polished metals may be obtained in various fabrications. Their effectiveness is dependent upon high reflective ability, and they offer the advantage of light weight where accessory supports or reinforcing are not necessary. Silica aerogel, a processed water glass, now available in powder form, for temperatures up to 1,500 deg. F., offers the advantage of light weight.

Exfoliated mica in granulated or block form, known as vermiculite (aluminum magnesium silicate) for medium and high temperature ranges up to 1,600 deg. F. is a new development.

Diatomaceous silica base products can be used for the range from 600 to 2,500 deg. F. They come in natural state or mixed with asbestos fibres for the lower range, and calcined or burned with clay for higher temperatures. Bauxite monohydrate insulations are also being produced for this range by the chemical treatment of raw bauxite to which is added asbestos fibre.

Insulating bricks of high thermal resistance (low conductivity value), low specific heat, and a high degree of refractories are available in several types for temperatures up to 2,000 deg. F. They can be placed back of insulating firebrick or used directly as a liner where there is no flame impingement, slag action or mechanical abrasion as in annealing furnaces, heat-treatment furnaces and muffle type furnaces. Crushing strength and small resistance of this insulant are important characteristics to be considered.

Cement forms of insulation are also useful in the moderate and high temperature ranges but care must be taken to select a type designed for the particular purpose to which it will be applied. Where blanket, block or sheet insulation are not adaptable on irregular surfaces, 85 percent magnesia, vermiculite, diatomaceous silica or mineral wool cements are used. As these do not provide a smooth finish, the last layer requires the admixture of portland cement or a finish coat of reinforced asbestos cement. Asbestos cements are economical and ideal as a finish for primary insulants and can also be used to insulate small fittings in the medium temperature range.

Castable refractories, recently developed, which consist of selected refractories crushed to definite size and mixed with lumnite cement, are suitable for temperatures ranging from 2,000 to 2,800 deg. F., depending upon the type of aggregate used. Densities also vary over a wide range; lower density materials are generally the better insulators. Usually supplied in dry form, such materials need only to be mixed with water on the job.

Insulating concrete made from granulated calcined diatomaceous silica and portland cement applied about 2 in. thick, reinforced with suitable steel mesh, has given excellent results where extended fire protection is desired. It

is relatively expensive because of the form work involved. High temperature insulating blocks have also been used with success. Block insulation is secured to the outside of steel beams or columns with nichrome or similar wire, and any spaces formed by reentrant angles can be filled with loose material of the same composition as the blocks. The surface of the insulation is then protected with a coating of semi-refractory cement.

Installation of Insulants

For industrial work, galvanized steel strap, machine stretched and clamped, is an ideal support for block or blanket type insulation. Strap ½ x 0.015 in. has been found satisfactory for equipment under 10 ft. O.D., and ¾ x 0.02 in. strap is suitable for equipment 10 ft. or more in diameter. If bands are placed underneath lapping sections of the weatherproof jacket on outside work, the probability of insulation becoming loose because of fastening failure is decreased.

Expansion joints can be insulated with mineral wool blanket fabricated between ⅜-in. rib lath on one side (ribs in), and expanded metal lath on the other. Strips should be cut in sufficient widths to properly overlap expansion joints, width of strips should run in the same direction as the lath rib. These mineral wool strips should be securely laced to the adjacent duct insulation, followed by a layer of high temperature cement, and finished when dry with a mixture of asbestos and portland cement in the same manner and to the same finished thickness as specified for adjacent insulation. For breechings and ducts suitable provision must be made for expansion, so that the joints will have freedom of movement without disturbing insulation.

All outside corners of insulation on hot air ducts or breechings should be protected with galvanized corner bead securely fastened over block insulation with No. 14 galvanized iron wire. Corner bead should be set so as to provide a true line and finish flush with the final coat of cement.

For the finishing of insulation on duct work and large pieces of equipment, a mixture of portland cement and long fibre asbestos, in the ratio of three to one, for the last ¼ in. coat has been found desirable in place of the standard canvas finish, this eliminates the possibility of flash caused by heat leakage through joints or cracks in the insulant.

Before insulation is applied to flanged heads of equipment, ½ in. blank nuts or other approved fasteners should be installed on suitable centers around circumference of the heads, approximately 3 in. from intersections with flanges to provide fastening for insulation tie wires. Also, when bottoms are to be insulated, suitable tie wire fasteners should be provided.

Wherever corrosion might result from electrolytic action, all wire mesh and metal lath reinforcing should be cut back where necessary to avoid contact with vessel projections, particularly for aluminum equipment.

Where hangers support refrigerating equipment directly, each hanger should be insulated in the same manner as the equipment for a distance at least 12 in. beyond the equipment insulation, and the sealing membrane carried at least 6 in. over adjacent insulation.

Industrial equipment operating at low temperatures should have all brackets insulated with the vessel as part of the vessel area. Beams supporting brackets should be insulated for at least 12 in. each side of the bracket. Where pipe nozzles, ladder clips and level gage brackets project through the insulant, they should be flashed with black asbestos roof putty. Insulation of low temperature equipment should generally include insulation of all blind flanges and nozzles.

Equipment located close to the floor or other areas where there is danger of mechanical abuse should be protected by means of a sheet metal jacket. Insulation should be stopped short of flanges and beveled off at 45 deg. to permit easy removal of flange bolts.

In applying insulation jacketed with canvas, weatherproofing felt or other flammable materials, care must be taken to cut the jacket away from all hangers, brackets or hot projections to avoid possibility of scorching or fire. These areas should be given a hard, smooth, asbestos cement finish.

Weatherproofing

Insulants exposed directly to the weather should be suitably protected. Asphalt-saturated asbestos or rag felt jackets appear to be satisfactory where the type of equipment permits the use of such materials. Where a regular program of maintenance inspection is not followed, the asbestos jacket offers some advantages in not requiring periodic coating. Metal jackets can be used, but they are usually expensive and require careful construction to provide the complete protection required. On irregular surfaces or types of equipment where the jacket materials cannot be used satisfactorily some plastic weatherproofings have proved suitable. Because of fire hazard, restrictions against the use of hot asphalt or other coatings with volatile solvents have led to the use of emulsified asphalt mastics which give a cold, odorless protective coating even to wet surfaces.

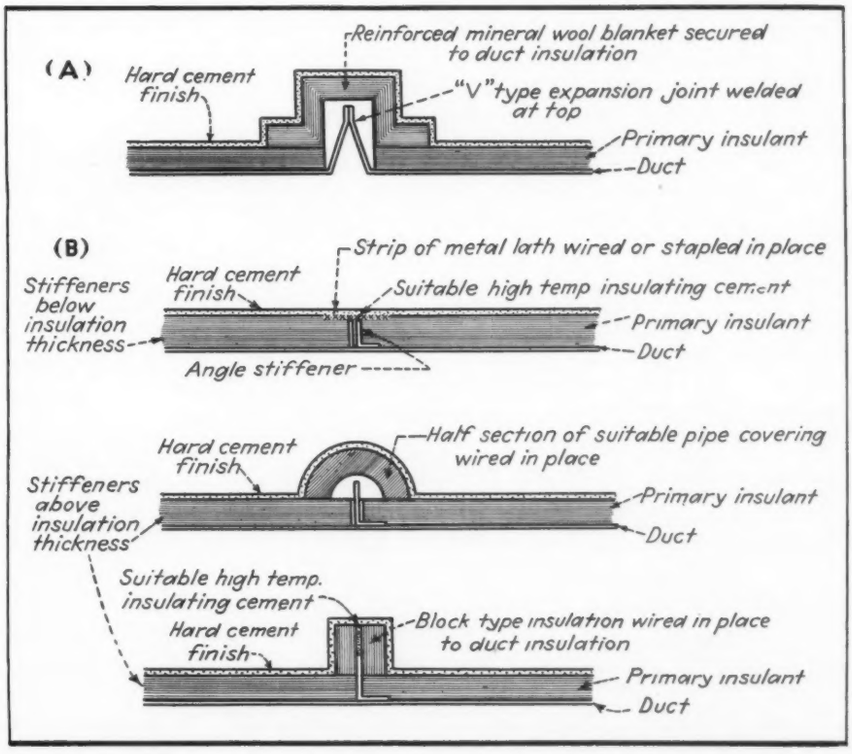


Fig. 4.—(A) Method for insulating expansion joint, (B) Methods for insulating duct stiffeners having a height less than and also greater than insulation thickness

Things to Consider When

HORACE C. HILLMAN
Production Engineer, Lockheed Aircraft Corporation

MANY PROPER and improper ways to design molded plastic parts are illustrated on the following pages. In addition to these graphic rules, the following general precautions, if heeded, will avoid production and service troubles.

1. Avoid re-entrant curves and undercuts. Extend internal bosses to bottom of closed area to prevent undercuts.
2. Round external corners except at parting lines. Fillet internal corners.
3. Avoid abrupt changes in thickness and in cross-section.
4. Avoid sections over 1 in. thick in thermosetting materials or over 0.25 in. thick in thermoplastic materials. Thick pieces increase cure time.
5. Reinforce flat surfaces at corners.
6. To avoid possible breakage, ratio of length to thickness for unsupported projections should not exceed 2:1.
7. Minimum web thicknesses for molded parts are 0.03 in. for unfilled and 0.05 in. and up (depending on filler) for filled plastics.
8. Parts subjected to corrosive agents must avoid entrapment of these agents.
9. Locate lettering on surfaces parallel to parting plane.

MINIMUM TOLERANCES FOR MOLDED PARTS

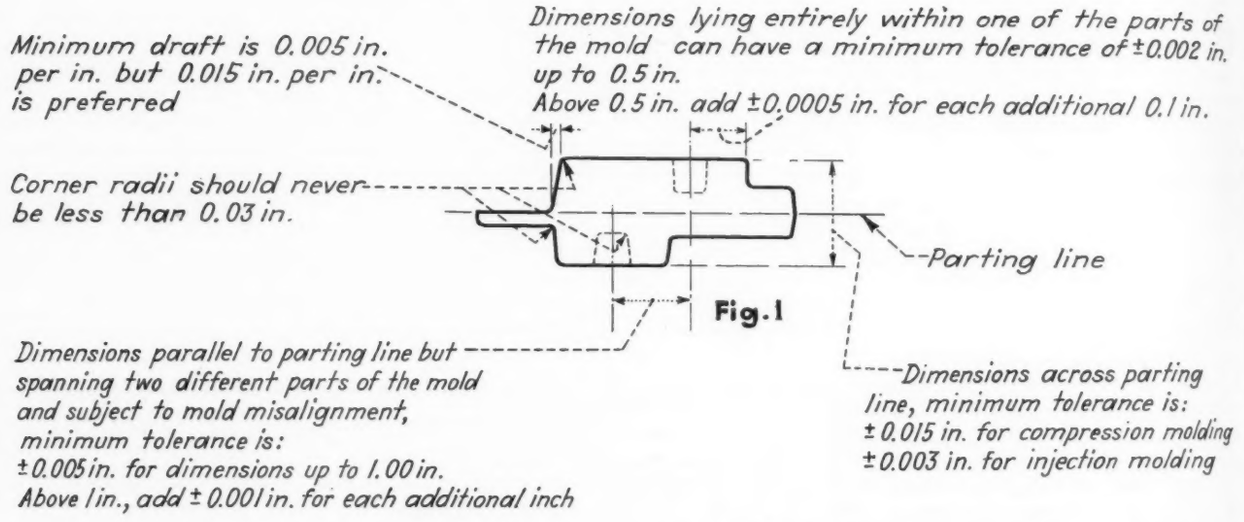

Minimum draft is 0.005 in. per in. but 0.015 in. per in. is preferred
Dimensions lying entirely within one of the parts of the mold can have a minimum tolerance of ±0.002 in. up to 0.5 in.
Above 0.5 in. add ±0.0005 in. for each additional 0.1 in.
Corner radii should never be less than 0.03 in.
Parting line
Fig. 1
Dimensions parallel to parting line but spanning two different parts of the mold and subject to mold misalignment, minimum tolerance is:
±0.005 in. for dimensions up to 1.00 in.
Above 1 in., add ±0.001 in. for each additional inch
Dimensions across parting line, minimum tolerance is:
±0.015 in. for compression molding
±0.003 in. for injection molding

Fig. 1—The tolerances indicated are minimum. Greater tolerances should be specified, if such are permissible, as they usually result in better qualities and lower costs. Permissible draft should be specified on the drawing by a general note such as: "Note: Draft of 0.015 in./in. max. unless otherwise noted"

LOCATIONS OF INSERTS

Fig. 2

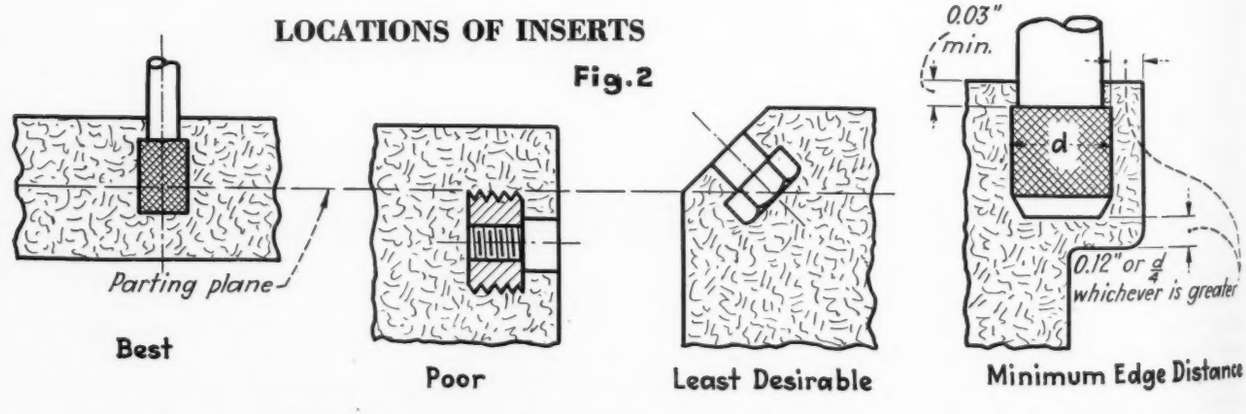


Fig. 2—Inserts should be located perpendicular to the parting plane; parallel to the parting plane is poor design; oblique is least desirable. Minimum edge distances or distances to the surface are as given in the sketch to the extreme right. For lightly loaded unfilled parts the inserts may be located slightly closer to the surfaces, but in no case should the knurled or gripping area of the insert be less than 0.03 in. below the surface

Designing Molded Plastic Parts

SIZE OF INSERTS AND SERRATIONS

MATERIALS WITH COARSE FILLERS such as macerated fabric or fibre not only require stronger inserts to resist increased flow pressure, but the inserts must have large serrations or grooves (0.05 in. min.) to allow sufficient grip. Non-filled materials permit inserts to have shallow gripping means (0.01 in. serrations) and greater contact area.

TOLERANCES AND POSITIONING OF INSERTS

INSERTS WITH LARGE TOLERANCES are to be avoided as it is difficult to fit them properly in the mold. Inserts that depend upon closure of the mold to position them firmly are not satisfactory for compression molding. Such inserts can be used satisfactorily in injection molding wherein the molds are held tightly closed before the plastic material is injected.

WRONG AND CORRECT DESIGNS OF INSERTS

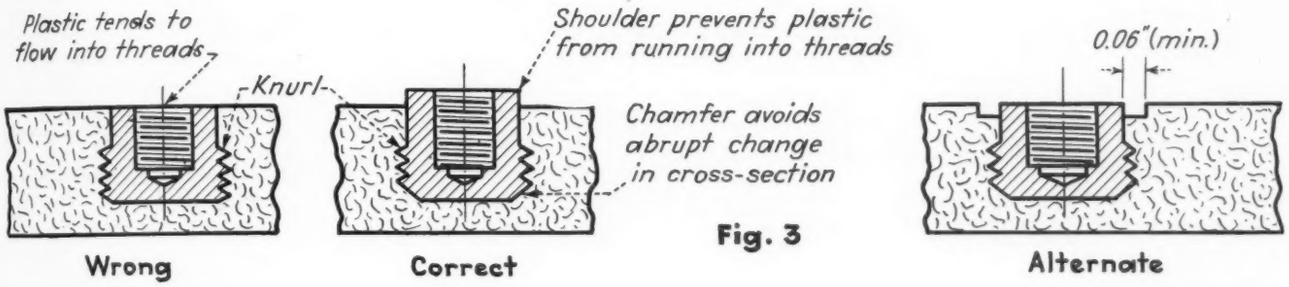


Fig. 3

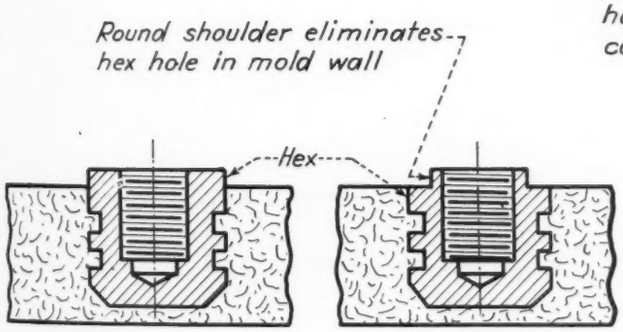


Fig. 4

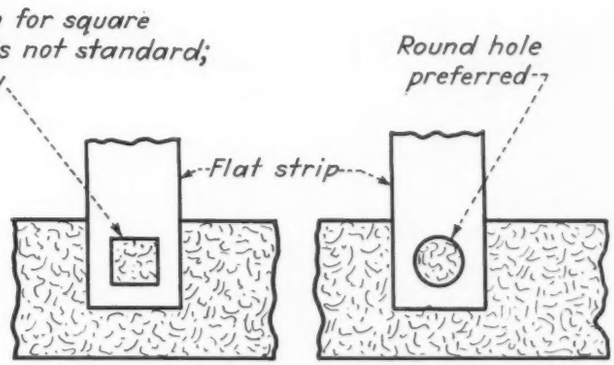


Fig. 5

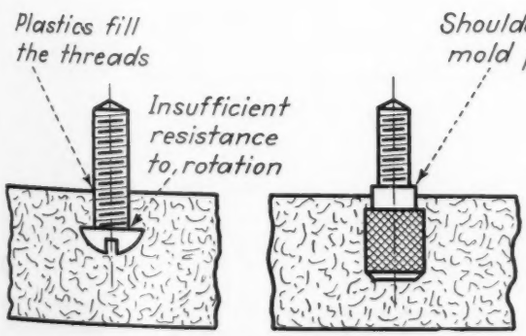


Fig. 6

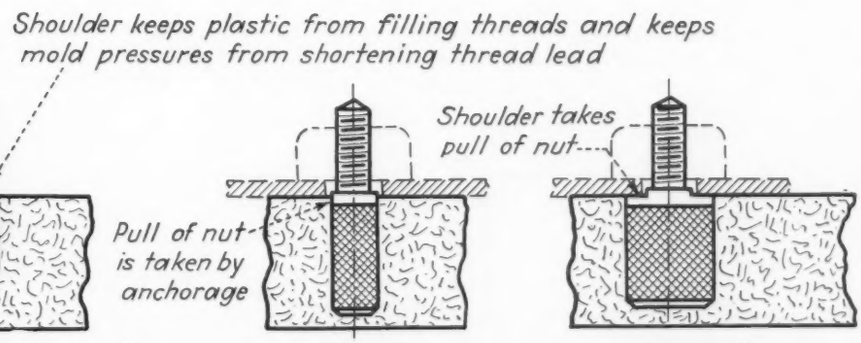

Shoulder keeps plastic from filling threads and keeps mold pressures from shortening thread lead
Shoulder takes pull of nut
Pull of nut is taken by anchorage
Wrong
Correct

Fig. 7

(continued on next page)

Designing Molded Plastic Parts (continued)

MISCELLANEOUS INSERTS

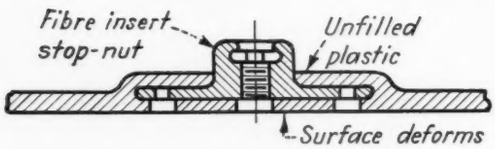


Fig. 8

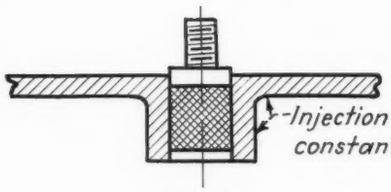


Fig. 9

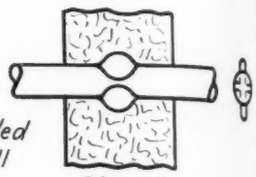


Fig. 10

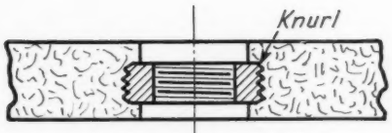


Fig. 11

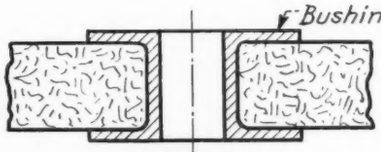


Fig. 12

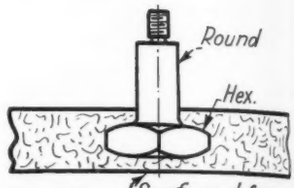


Fig. 13

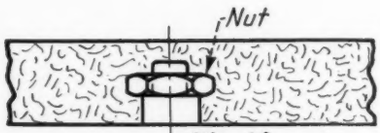


Fig. 14

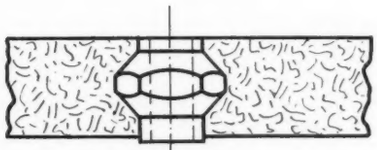


Fig. 15

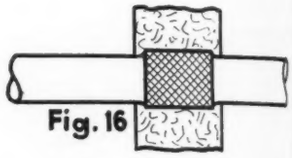


Fig. 16

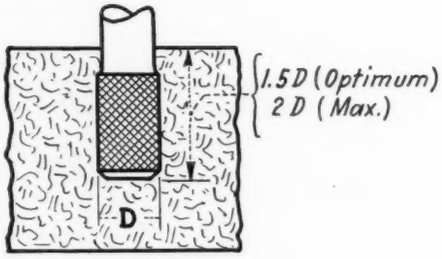


Fig. 17

Correct proportions for imbedded portion of insert

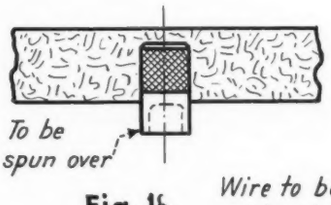


Fig. 18

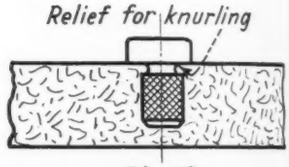


Fig. 19

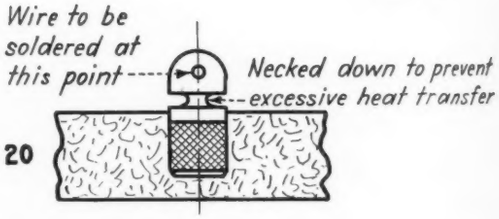


Fig. 20

DESIGN OF MOLDED THREADS

Do NOT MOLD THREADS on or in a part unless there is a means of gripping it to remove it from the mold. Do not mold internal threads smaller than No. 10. External threads should be avoided; however, when used, they should not be molded smaller than ¼ in. External threads are more accurately injection molded than compression molded. Molded threads subject to assembly and disassembly in service should not be smaller than ½ in. in diameter. Use coarse thread series (Class 2) for molded threads. Threads should begin and end 0.03 in. from lug or hole extremities. Both right and wrong design details are shown below.

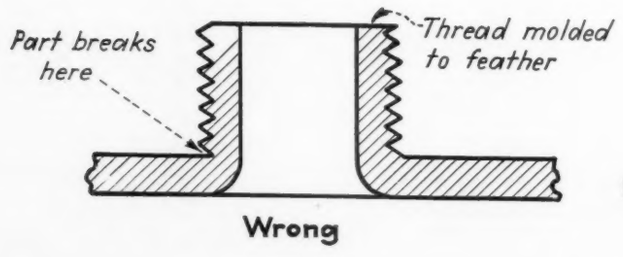
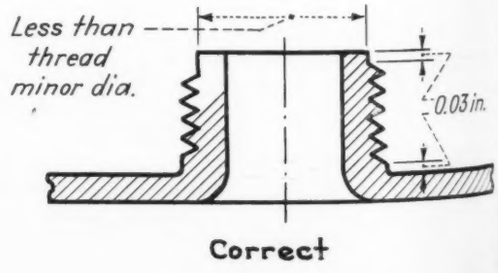


Fig. 21



CORES AND HOLES

THE USE OF CORES IN A MOLD increases both its cost and its operation cycle; therefore, designs requiring cores should be avoided. When cores are necessary, they should be: 1. perpendicular to parting plane (best); 2. parallel to parting plane (poor); 3. oblique (least desirable). Long slender cores should never be used unless they can be supported at both ends. Holes which are not perpendicular to the parting plane are sometimes more economically drilled than molded. Blind holes should not be deeper than 1½ diameters in compression moldings nor 2½ diameters in injection moldings.

Fig. 22

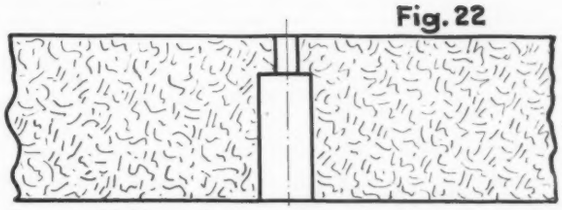


Fig. 22—Molded "through" holes if of an appreciable length, should preferably be of two diameters, having the larger diameter extended over the greater portion of their length

LOCATION OF PARTING LINES

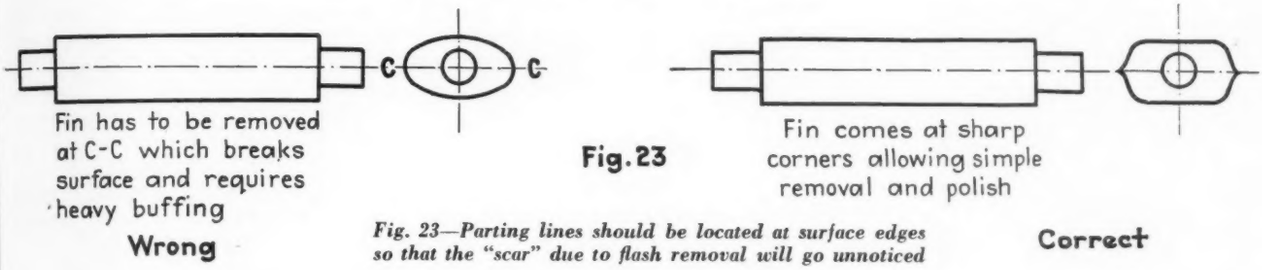

C
C
Fin has to be removed at C-C which breaks surface and requires heavy buffing
Wrong
Fig. 23
Fin comes at sharp corners allowing simple removal and polish
Correct

Fig. 23—Parting lines should be located at surface edges so that the "scar" due to flash removal will go unnoticed

DESIGN WEAKNESSES TO BE AVOIDED

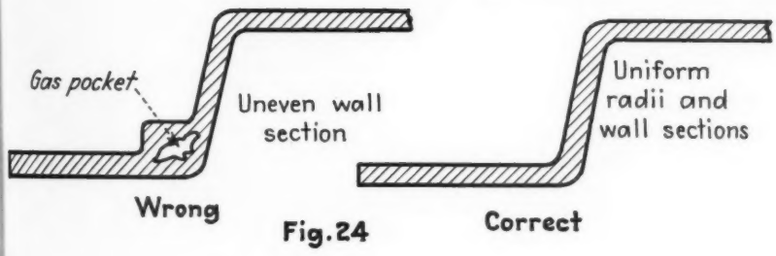
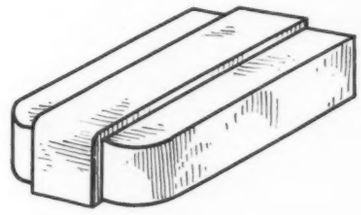


Fig. 24—Avoid abrupt changes in thickness and in cross-section



Flat areas requiring reinforcement at corners

Wrong

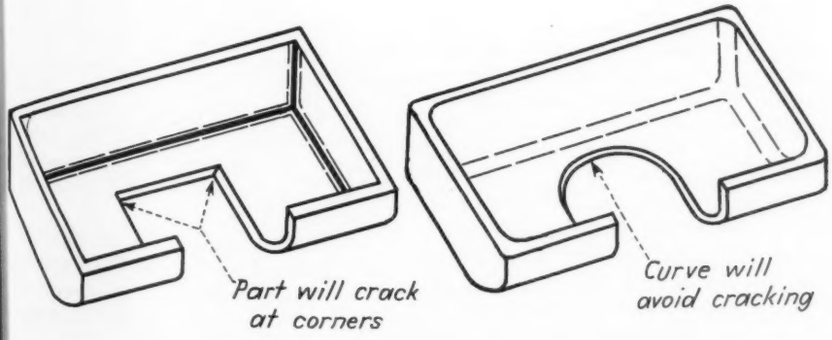
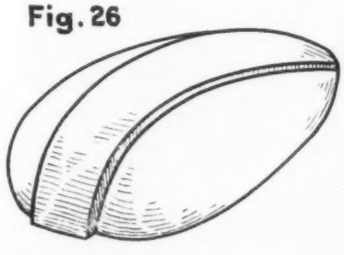


Fig. 25—Sharp corners are always likely to crack and therefore should be heavily filleted on the inside. Slightly rounding the outside corner is a further improvement. Notches as shown above should not be square, but rounded

Fig. 26



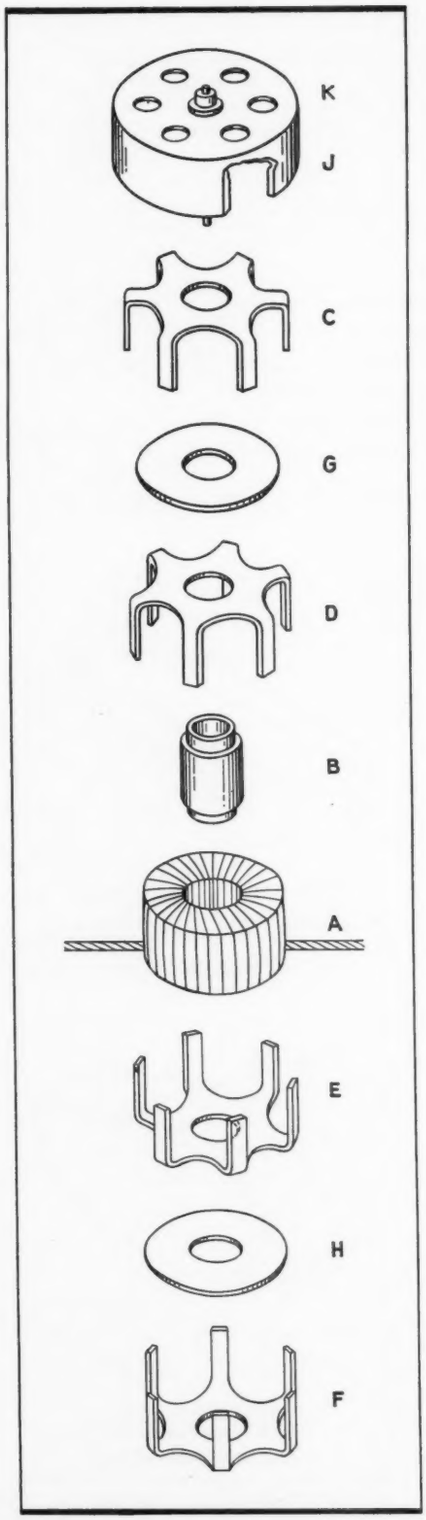
More uniform thickness and greater rigidity

Correct

Fig. 26—Double curvature and spherical corners, produced at increased tooling costs, result in more uniform thickness and greater rigidity

Synchronous Motor Designed for Starting Torque and Slow Speed

PAUL MacGAHAN
Meter Division, Westinghouse Electric & Mfg. Company



SLOW-SPEED has long been a goal in the design of miniature synchronous timing motors in order to eliminate the high-speed gearing usually required with such motors. The gearing not only adds to the cost but, of greater importance, takes a substantial fraction of the extremely small power output of the motor. The ideal miniature synchronous motor is one having synchronous speed, starting torque and low speed. Such a motor, using the hysteresis principle, has been designed by B. E. Lenehan, Westinghouse Meter Division, for use in demand meters, two-rate meters, recording instruments and time switches where a high order of reliability and long life are required. This motor operates at 600 r.p.m. in a 60-cycle circuit.

Synchronism is effected by magnetic attractions between the rotating field formed by the pole pieces and the remanent unidirectional magnetization of the armature. Starting torque results from iron loss or magnetic lag in the steel rotor; hence the term hysteresis.

Briefly, the motor consists of a circular coil field, the center core of which joins two sets of polar projections that fit together alternately, forming 24 pole pieces. Each pair of pole pieces is subdivided into a main and a shaded pole—all six shaded poles of one polarity being lagged by a common short-circuiting ring. The rotor is an aluminum cup supporting the active remanence member consisting of a thin strip of hardened steel. This steel becomes magnetized like a permanent magnet as soon as the motor reaches synchronism, and because of this "remanence" will continue in step with the alternating current frequency as applied to the coil. The entire rotor weighs only 5½ grams.

In Fig. 1 is shown the principal parts of the motor. Operating coil *A* magnetizes cylindrical core *B*, which is assembled to four pole-piece punchings, *C*, *D*, *E* and *F*, each having six polar projections. When assembled with the core these projections surround coil with 24 cylindrically arranged poles.

Fig. 1 (Left)—Exploded view of Westinghouse synchronous clock motor

There are two sets of paired six-pole punchings, each separated by copper washers *G* and *H* which act as phase splitters causing alternate poles to lag behind the others and resulting in an elliptical rotating field derived from the single phase coil winding.

Since two sets of pole-pieces are attached to opposite ends of the central magnetic core, their phase angle is opposed or 180 deg. displaced from that of the pole-pieces at the opposite end. This results in a 12-pole magnetic field with each pole "split" or lagged approximately 45 deg., giving a synchronous rotor speed of 10 revolutions per second in a 60-cycle circuit.

This rotating field enters a hardened steel rotor ring *J* in the cup *K*. Starting

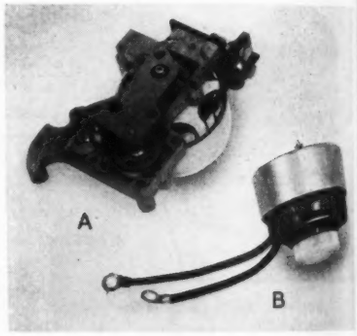


Fig. 2—(A) Motor arranged for open gearing drive. (B) Motor with inclosed oil sealed gearing is about 2 in. in dia.

energy is transferred across the air gap and produces a torque because of hysteresis loss in the steel ring. When speed reaches synchronism, the hysteresis disappears and running or synchronous torque is developed by remanent magnetization in the steel ring which retains 12 "permanently" magnetized polar zones corresponding to the 12 pole-pieces.

These poles lag at a slight mechanical angle behind the rotating magnetic field-poles, resulting in the magnetic attraction which produces the necessary running torque.

As in other synchronous motors, this angle increases with load until it exceeds a critical value after which the motor gets out of step or perhaps stops altogether.

WAR MATÉRIEL

Design • Developments

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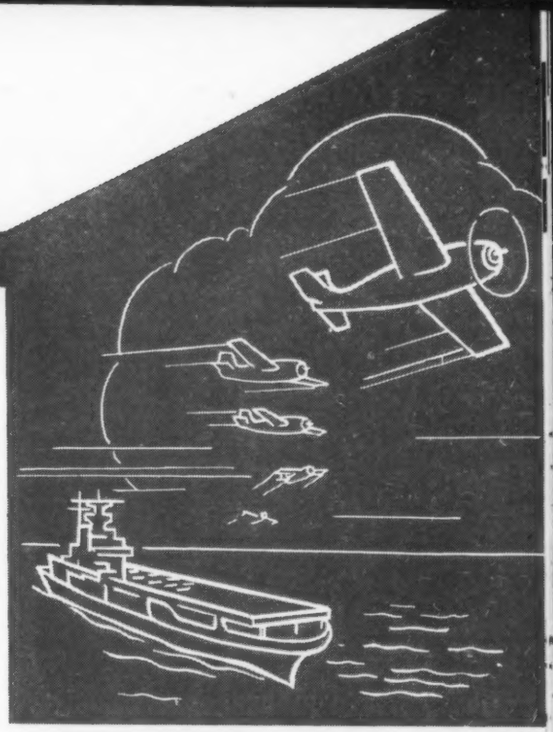
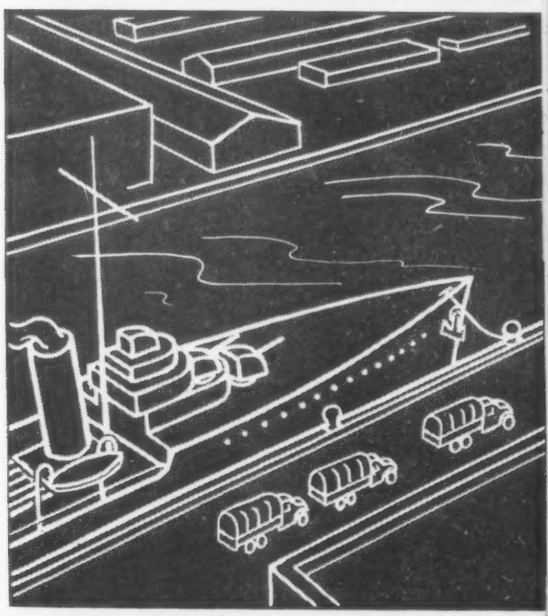
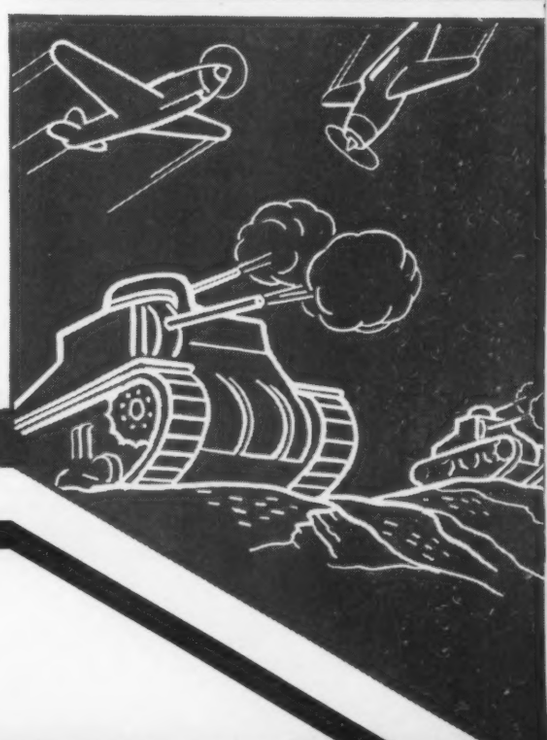






The Amazing Imitators

Revealed by Jap Wrecks At Pearl Harbor

Studies of the designs of wrecked Japanese planes, made by American Air Forces engineers, revealed that the Japs obviously attempted to copy selectively, choosing from among various American designs those features which they considered outstanding. The technique followed, what they accomplished, and the probable state of Japanese aeronautical engineering are set forth in this article, based upon reports by the Army Air Forces and released for publication by the Bureau of Public Relations, War Department.

LONG BEFORE the war began the Japanese had already established a reputation as imitators. But even today the extent to which the Japs copy designs, the technique they use, their reasons for copying and the significance of it are not generally recognized. The common impression is that the Japanese copy because they are incapable of design originality.

In order to understand the reasons for and implications of the deliberate theft of American airplane designs by the Japanese, one must consider the history of the Japanese aircraft industry. Until 1926 Japan bought all her airplanes from the United States and European countries. Then she began developing her own aircraft industry. In order to get the new industry started quickly, the Japanese began manufacturing airplanes under foreign licenses, paying royalties on the planes built according to the designs furnished by American and other foreign plane builders. They purchased in the United States many airplane parts, including complete engines, instruments and propellers. This continued until 1937 when the Japanese began manufacturing planes of their own design, including all the parts and engines. They needed planes for their war in China and foreign relations were becoming strained. Whether or not they foresaw the coming conflict with the United States at that time is not known. But it is an established fact that in 1937 Japan took quick steps to relieve herself of all dependency on foreign manufacturers for the building and equipping of her airplanes. A new industry was to be created as quickly as possible.

Starting from scratch it would have taken the Japanese many years to develop successful new designs of airplane engines and accessories. To save this time they adopted a quick and simple method; they copied the designs of the equipments they had purchased previously. Such a procedure had another important advantage. Presumably the Japanese had bought considerable quantities of accessories and parts to be used for spares. By copying the foreign designs, the parts they built from the stolen design were interchangeable with the purchased foreign parts. As for the legality or ethics of such a procedure, one can hardly assume that such considerations were even discussed.

Up to the time of Pearl Harbor it was generally assumed that the Japanese made complete and exact copies of American airplane equipment. But when U. S. Army Air Forces engineers checked the designs of the Japanese planes brought down at Pearl Harbor, a quite different state of affairs was

TYPICAL JAPANESE PLANE PA

ZERO FIGHTER

Name of Part	Designs Copied from	Remarks
Engine		
Cylinders	Wright R-975-7	Similar
Nose Section	Farman type	Same as Wright
Power Section	14 cyl. Pratt & Whitney	Copy
Valve Mechanism	Pratt & Whitney	Copy
Carburetor	Old type Stromberg	Identical
Generator	Eclipse Type G-1	Identical
Starter	Eclipse B-11	Good Copy
Fuel Pump	Romec F-4	Copy
Propeller	1937 Hamilton Standard Type 3E50-279	Practically a perfect copy
Landing Gear Brakes	Bendix	Similar
Instruments		
Compass	Fairchild	American Made
Loop Control	Fairchild	Copy
Hydraulic System		
Oil Strainer	Cuno #12547	Similar

revealed. It was quickly discovered that the Japanese had a copying technique that was quite original. They copied indiscriminately, picking and choosing designs of parts and design features, frequently incorporating into their imitation various details selected from several different designs of the part they were copying.

When the power-plant engineers of the Army Air Forces analyzed the design of the engines of the Zero fighters brought down at Pearl Harbor, they found the engines to be an amazing conglomeration of parts from various makes of American engines. A complete and detailed listing of engine parts copied from American designs would become monotonous reading. Some of the more significant items are listed below.

Apparently the Japanese technique of imitating as revealed in the engine of the Zero fighters built by the Nakajima Company was used in the design of all their engines. Similar copying practices were found when the engines of dive bombers built by the Mitsubishi Company were analyzed.

Practically all the other equipment on the Japanese airplanes brought down at Pearl Harbor was found to be, upon examination by the Air Corps engineers, copied from American and other designs. The hydraulic hand pumps and many of the units in the hydraulic system are copies or modifications of American designs. The oil strainer in the hydraulic system is similar to the Cuno No. 12547, modified only slightly. The radio equipment is largely of German design with a few American parts, and the units are mounted on vibration insulators of Lord Manufacturing Company design. Compasses are Fairchild make, as also are the remote compass dial control and loop control. The air speed indicator, fuel quantity indicator and the oxygen regulator are all copies of American designs, the last a poor imitation of a Bourdon tube type. The suction regulator is an exact copy of a Sperry design. The temperature indicator is an inferior copy of a U. S. Gauge Company instrument of the Bourdon tube capillary type, the capillary being poorly armored and the means for the instrument adjustment being crude.

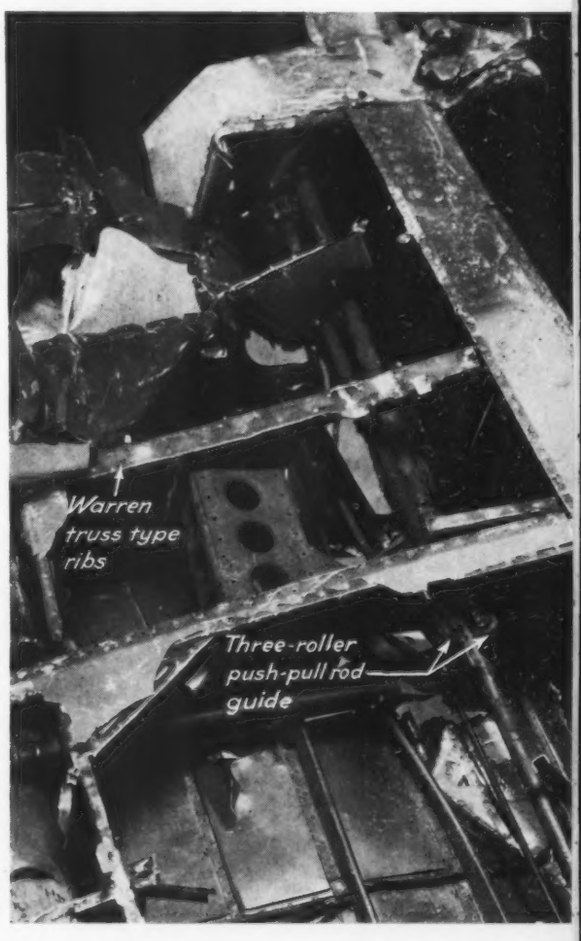
All of the instruments use metal cases and glass covers that are considerably heavier than those on American instruments. They are appreciably inferior, both in design and workmanship, with few exceptions. The pitot tube design is one. It is electrically heated and has an ingeniously designed cleverly demountable head, making possible the changing of the entire head by simply unscrewing a retaining nut. Both the velocity and static tube connections are made automatically when the retaining nut is tightened.

The Zero fighters have adjustable pitch propellers that are almost identical with the Hamilton Standard 3-E50-279 series of 1937 design. The aluminum alloy blades are apparently perfect copies and many of the internal parts of the propellers have the identical part numbers as listed in the Hamilton Standard parts catalog.

One might conclude that because so many parts of the Japanese planes were found to be copies of obsolete American designs, the Japanese planes from which they were taken were old obsolete models. However, the dive bombers analyzed were Aichi Model 99, the model number, according to the Japanese system of assigning such numbers, indicating that this plane model was first produced in 1939 and that the particular airplane shot down was made in 1941. This conclusion is further borne out by the translation of the nameplate found on the actuating cylinder for the flap controls. It reads, "Made in Japan. 15th year of His Imperial Majesty. August 19. Actuating cylinder flap. 99 Model Carrier Bombardment Airplane. Certified pressure 66 kg. per sq. cm. Weight 1.775 kg." The "15th year of His Imperial Majesty" is 1941, which agrees with the year indicated by the model number.

Workmanship on the Japanese airplane engines and machined parts usually ranges from good to excellent but it seems to be Japanese practice to machine as few surfaces as possible. This is strikingly shown in the gears, the teeth of which have a finish that compares favorably with American practice, but the webs and hubs are not well finished. One might conclude that the Japanese are short on machine tools and skilled mechanics.

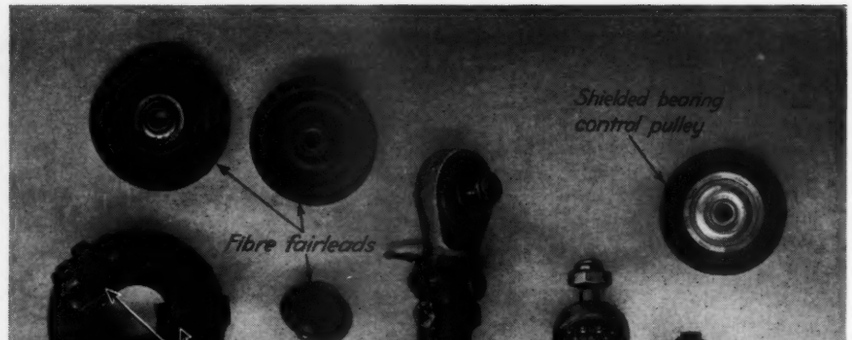
Jap wing structures indicate a scarcity of extrusions. Wing spars are built-up I-section, ribs are Warren truss type, members being formed channel sections



PIED FROM AMERICAN DESIGNS

AICHI DIVE BOMBER MODEL 99

Name of Part	Designs Copied from	Remarks
Mitsubishi Engine		
Reduction gears	Pratt & Whitney	Exact copy but finish not up to American standards
Cam Assembly	Gnome-Rhone	Exact copy
Crankshaft	Pratt & Whitney	Similar
Pistons	Jap design	Incorporate P&W and Wright features
Cylinder head	Pratt & Whitney	Modified
Supercharger	Wright	Close copy
Instruments		
Temperature Indicator	U. S. Gauge Company	Poor imitation
Pressure Gages	(U. S. Gauge Company and Pioneer Instrument Company)	Exact copies
Suction Regulator	Sperry	Exact copy
Vibration Isolators for Mountings	Lord Mfg. Co.	Exact copy
Cowl Fasteners	Dzus design	Identical



Parts of the control system. The ball bearings are held in the push-pull rods by retaining shields screwed and staked into the side faces of the rod ends—a construction similar to that found in German JU-88 bombers

which is probably true. This is further indicated by the fact that the Japanese gages and instruments are of distinctly inferior workmanship.

In contrast to the engines, the designs of the Japanese airplane structures are not direct copies of foreign planes and exhibit some degree of originality. This is partly explainable by the limited plant capacity of the Japanese to make extruded aluminum sections and hence they could not copy American designs which use extruded sections extensively. But aside from this, the Japanese did incorporate some originality in the design of their plane structures.

Instead of using extruded sections for the main spars of the Aichi dive bomber, the Japanese use a solid web with a cap strip built up of layers of aluminum strips, as many as seven, riveted together and secured to the web by riveting to formed angles. There are no lightening holes in the web. The spars carry all of the weight of the plane; the structure is not skin stressed. The wing ribs are all built up, not stamped. The structure of the plane is considerably lighter and weaker than comparable American planes, a fact which also is true of the Zero fighter.

In the design of the Zero fighter, the Japanese not only sacrificed structural strength to attain lightness, but for the same purpose they discarded all protective armor. Taking advantage of the smaller stature of the Japanese pilots, the size of the cockpit and fuselage was made smaller than in American planes. All this resulted in a fighter plane with exceptionally high horsepower per pound weight of plane which explains why the Zero fighters are more maneuverable than the older models of the P40. But because the Zeros are structurally weaker, they cannot dive as rapidly. They are also slower on the straight-away because of the smaller horsepower of their engine.

The discovery of the absence of protective armor on the Zero fighters exploded the myth that Japanese pilots fight with suicidal intent. It is now quite well established that the Japanese pilots are usually killed even before the plane is disabled. Finally the plane with its pilot plummets earthward. Dead pilots can't bail out.

Another weakness of the Zero fighter is in the gasoline tank which is not bullet proof. Often the first round of shots punctures the tank and the leaking gasoline catches fire.

Many further interesting features were found when the Air Corps engineers made their investigation of the structural details and controls of the Zero fighters and Aichi dive bombers. The Japanese use flush riveting extensively. The skin sheets are 0.020 in. thick, the rivets are small—approximately $\frac{3}{32}$ in. diameter. All push-pull tube control joints have self-aligning ball bearing rod ends, the rod ends being held in the tubes by bolts with castellated nuts or by hollow rivets. The ball bearings are held in by retaining shields screwed and staked into the side faces of the rod ends. This construction is similar to that found in the German JU-88 bombers.

Long push-pull tubes are supported and guided through the wing ribs and at other points by guides in the form of three small rubber covered rollers set at 120 deg. to each other, each roller mounted on shielded ball bearings and all carried on the same bracket.

Ailerons, elevators and rudders have ball bearing hinges. Aileron control horns are external and have self aligning ball bearings. Control pulleys are of the shielded bearing type, similar to the AN210 pulley.

Apparently, the Japanese avoid the use of self-locking nuts and nut locks. For permanent fastenings or infrequent disassembly, they peen the bolt ends, although in a few places they use helical spring type lock washers or slotted and crimped plate nuts. Castellated nuts and cotters are used extensively and are of good quality. For fastening the cowls they use a quick opening fastener that is identical to the American patented Dzus design.

The scarcity of metal is evident in many places on the Japanese planes. Wood strips are used for reinforcing the edges of aluminum sheets used in spars and control surface structures. Apparently the wood strip is placed near the edge of the sheet and the sheet is then wrapped around it. The resulting structure is not as strong as the comparable American construction and it is probably used to save aluminum and as a simple substitute for extruded sections.

Many significant conclusions can be drawn from these studies of the designs of Japanese military planes. Admittedly the Japs did an amazing job of imitating. From long practice they obviously have become expert at it. In general, the workmanship throughout their airplanes must be classed as good but it reflects a scarcity of machine tool equipment. Surfaces are finely finished only where absolutely essential, with the result that many of the parts look crude and clumsy and obviously are inferior with reference to fatigue strength. The use of wood for reinforcing, linen tape for clamps, aluminum for the crankcase and the visual absence of extruded aluminum sections all reflect the Japanese scarcity of raw materials and their limited capacity for producing semi-finished forms such as extrusions.

It would be dangerous to conclude from all this that the Japanese are incapable of original design and first-class workmanship. As explained, one of the compelling motives for copying foreign designs was the urgent need for haste. But it is axiomatic that consistent copying will result in dulling the ability to do original work. The degree of this is debatable, but conceding all questionable arguments, one fact is definitely established. In view of the practically total absence of de-

sign originality in the Japanese engines, instruments and airplane accessories, one is forced to the conclusion that the Japanese do not have much in the line of research and development laboratories and qualified men to operate them. It is known that there are some outstanding and most excellent scientists and engineers among the Japanese, but only a limited number. The continued use by the Japanese of copied designs, many of which were abandoned by the U. S. Army Air Corps years ago, compels the conclusion that the Japanese do not have the engineering manpower to keep their designs up to date.

A marked shortage of Japanese aircraft engineering talent is indicated not only by the study of their designs but also by a consideration of the probable state of the Japanese aircraft industry. It would be unreasonable to assume that the Japanese have aircraft research, experimental laboratories and engineering departments capable of developing original and superior designs of military planes with any degree of speed comparable to that of America. Japan has relatively few engineers, probably less than 10 percent of the number of American technically trained men, judging by the enrollments in their technical universities and engineering societies. Nor has Japan had the time to develop research laboratories in aeronautics and have them now producing appreciable results. It takes ten years to get a research laboratory to the point where it begins to produce.

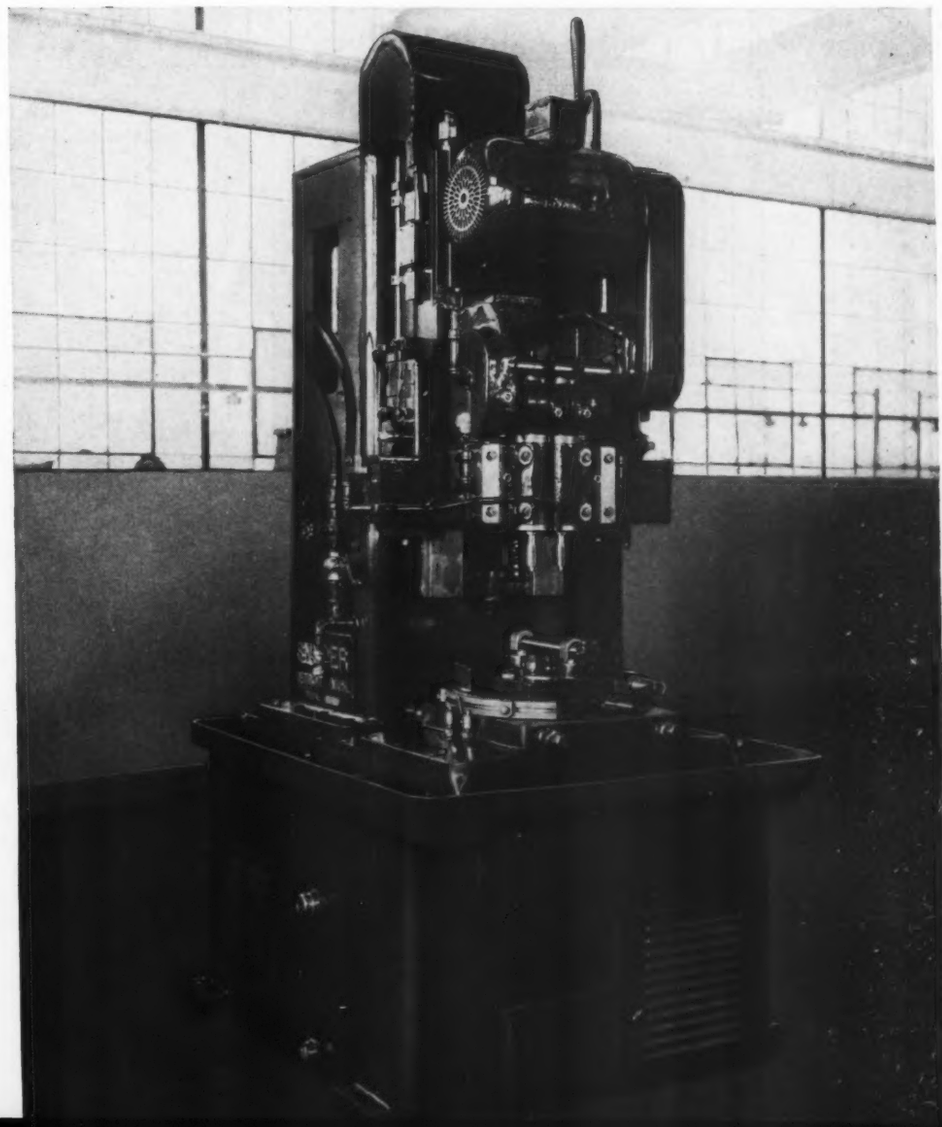
It is also evident from the examination of wrecked planes that the Japanese are not able to do much in the way of developing improved designs. Many of the parts taken from the planes were copies of American designs of ancient vintage, many of them dating back to 1937 and even 1935, although the planes themselves were built in 1941. The significance of this is that over a period of four to six years the Japanese did not find the time or did not possess the talent to either develop improved designs of their own or copy later models of American makes.

When hostilities began, the Japanese had fairly good airplanes with good engines. But already the effects of the overwhelming power of American engineering talent is beginning to be felt. It has already been demonstrated that the latest designs of U. S. military planes excel the best that Japan has offered. As time goes on, the relative superiority of the American military planes will increase while the Japanese engineers longingly wait for the opportunity to further enhance their well earned reputation as the amazing imitators.

WARTIME DESIGNS . . .

HYDRAULIC CONTROL SPEEDS MILLING OF AIRCRAFT PISTONS

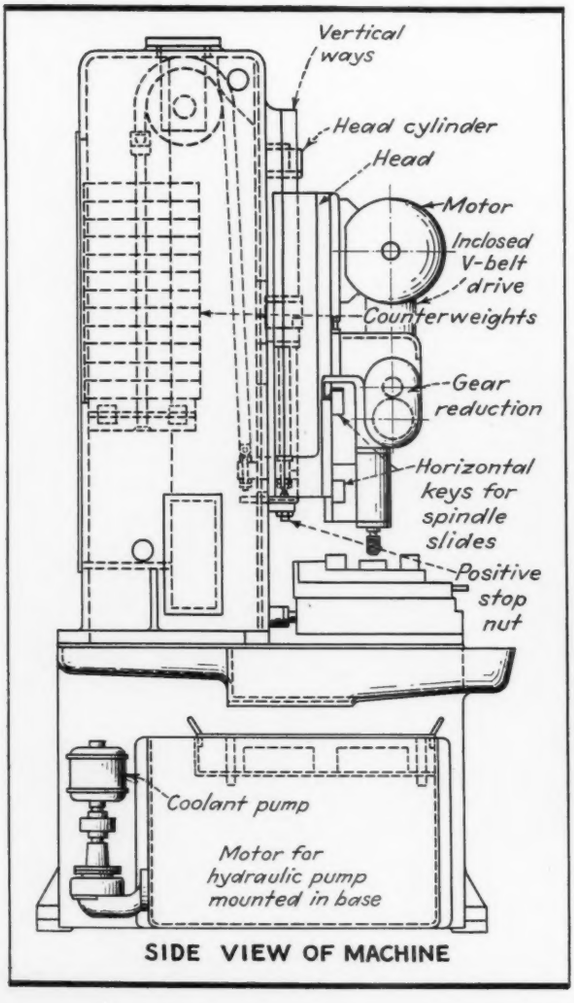
Design of this special-purpose machine by Snyder Tool and Engineering Company virtually doubles the production rate on milling the internal fins or relief in aircraft engine pistons. Snyder engineers incorporated two profile milling spindles on one machine with hydraulic control which moves cutters downward into piston. The spindles then "expand" outward to feed into the sides of the piston, the fixture table is rotated to mill the complete fins, and finally the spindles retract to starting position. Hydraulic operation, controlled by electric circuit, is automatic throughout the cycle, and assures positive movement against stops without damaging the machine. Details as described by William C. Oberem, Snyder's chief engineer, are given on the following pages.



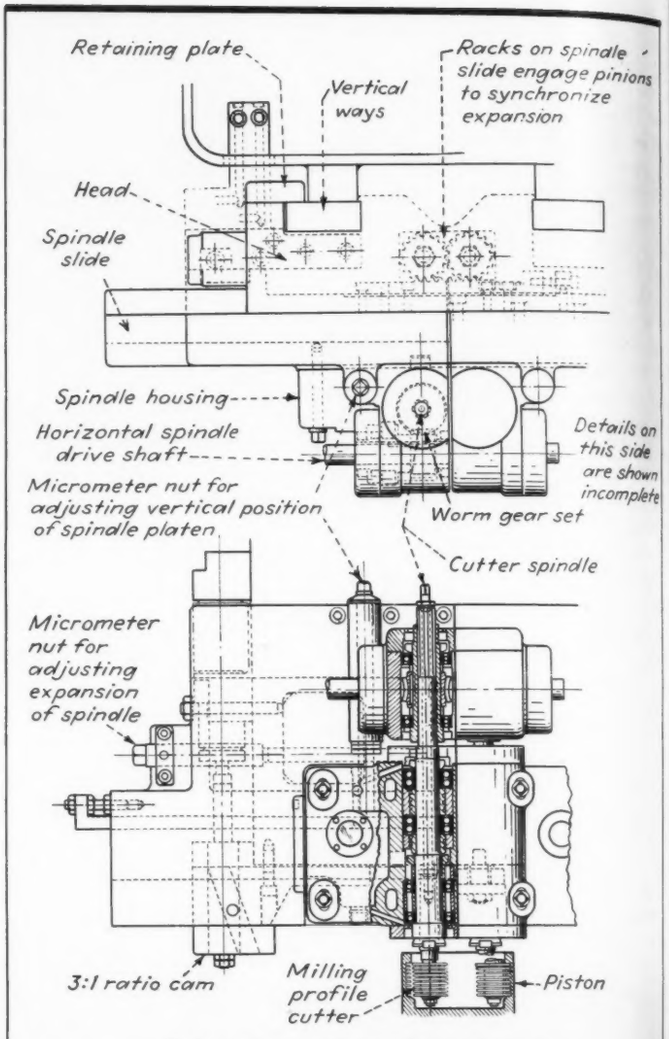
HYDRAULIC FIN MILLING MACHINE (continued)

Spindles of Snyder fin milling machine are ball-bearing mounted in separate platens which are bolted to slides mounted on head. Entire head, including motor drive unit, is moved up and down by 2½x12 in. hydraulic cylinder to give tool clearance for loading and unloading. Design of spindles and spindle drive had to meet problem of restricted center-to-center distance. Spindles are driven by 5-hp. motor through V-belts and pick-off gears. Speed selected allows sufficient horsepower to be transmitted to cutters. Two long, hardened keys on horizontal shaft permit the two spindle housings to "expand" laterally to feed cutters into work. Expansion of spindles is synchronized by rack and pinions. Spindles are kept parallel by two deep keys on spindle housings.

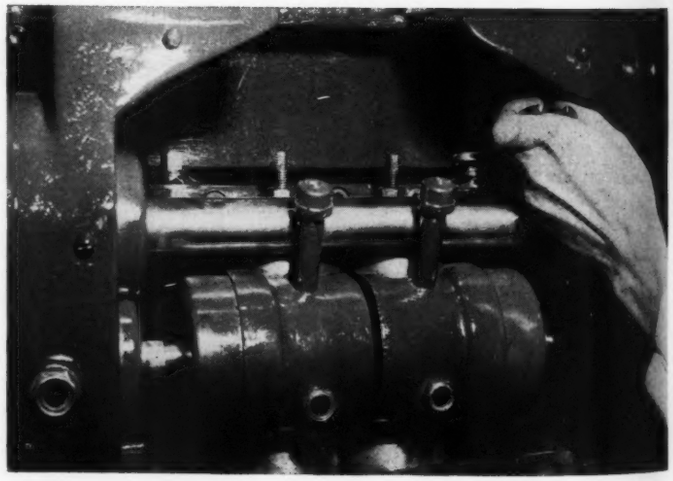
Interesting problems were met in design of hydraulic system: In spindle housing expansion movement, it was found that the cylinders required comparatively heavy pressures to move the slides; considerable trouble developed in lines feeding oil to these cylinders. Cure was to place cylinders in vertical position and transmit thrust through 3:1 ratio cams. Rotary table drive cylinders were originally 2¼ in. dia., but were enlarged to 3 in. dia. for smoother feed rate.



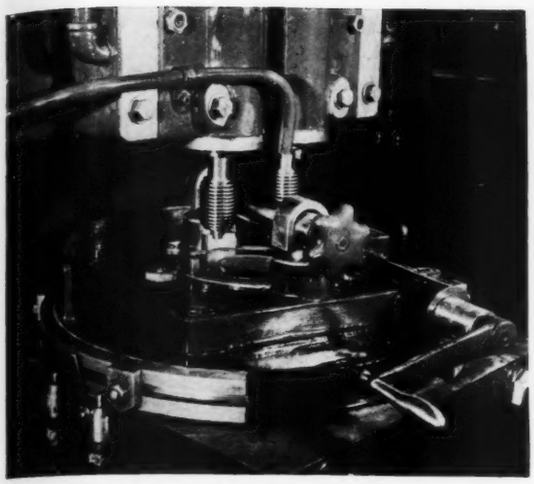
SIDE VIEW OF MACHINE



DETAILS OF SPINDLE DRIVE

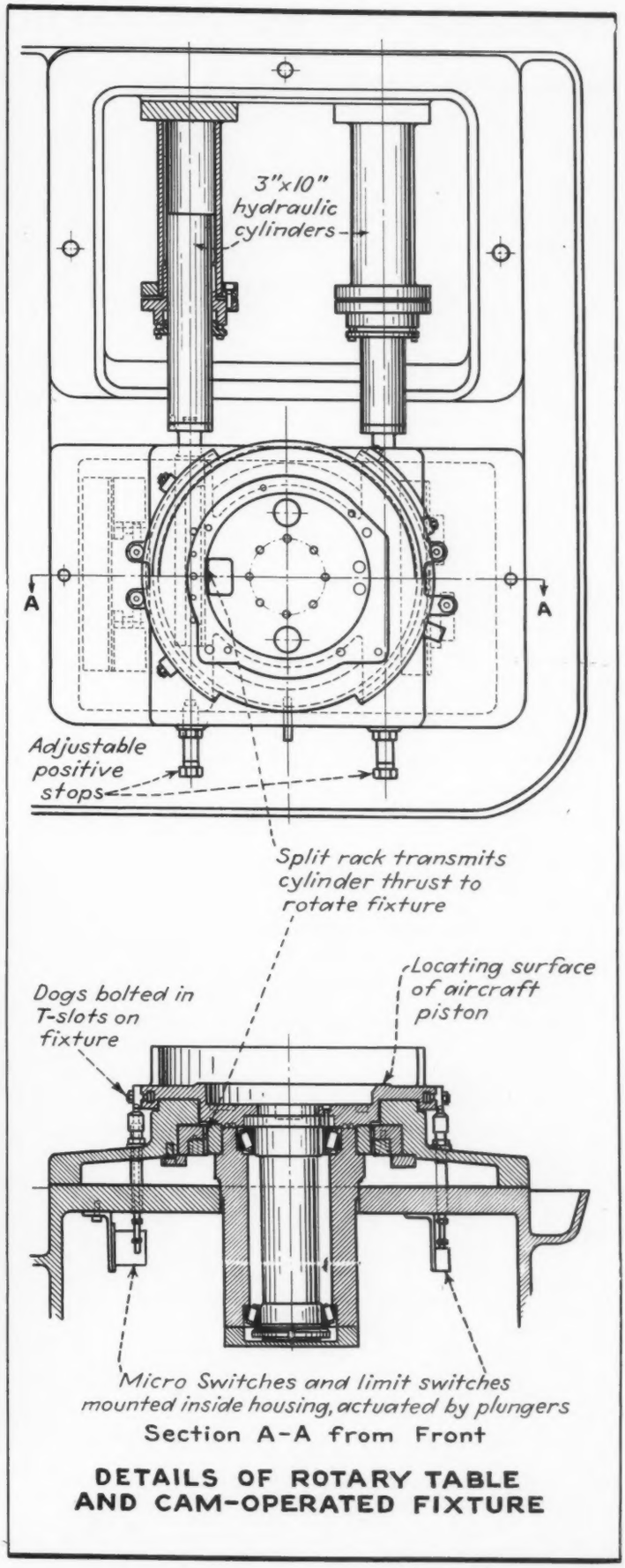


Vertical adjustment of spindle housings for elevation of cutters is provided by micrometer adjustment screws. Four bolts on each housing are loosened, micrometer screw is adjusted, and bolts are then tightened. Lowered position of head is adjusted by stop nut, following which fine micrometer spindle adjustments are made.



Rotary fixture table is driven by hydraulic cylinders through split-rack as shown at right. Solenoid valves feed oil under pressure to advance one cylinder; oil in other cylinder is forced out through metering valve which controls speed of rotation. See also schematic circuit, on following page. Photo above shows cutters in expanded position. Plungers shown are pushed down by dogs on rotating fixture to trip limit switches for reverse. Electric timer then continues feed for 1 to 2 sec. after solid stop is reached to insure completion of cut before reversing. Hydraulic system prevents damage that could be caused by overtravel in a mechanical system. Cover plate on front of machine gives easy access to switches. Piston is located and held on table by simple equalizing cam-operated device which grips wrist-pin inserted through piston.

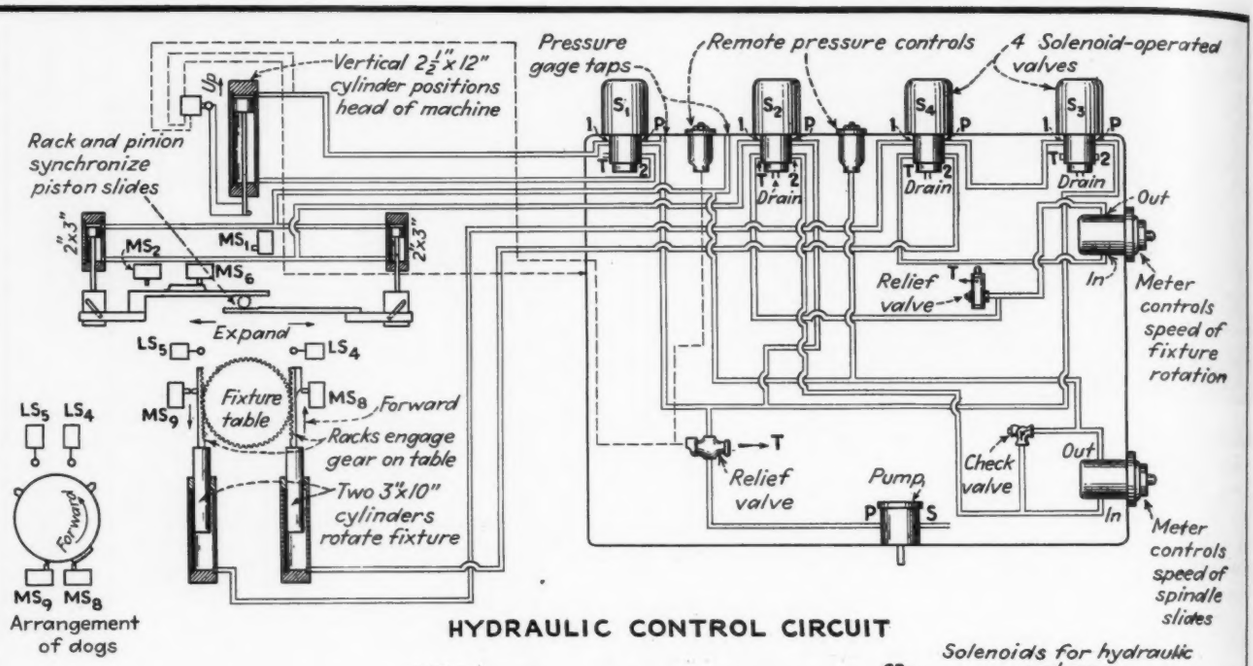
Depth of cut in fins is adjusted by micrometer stud screw against which the spindle housings come to positive stop after expanding. Variations in diameter of cutter caused by wear can easily be compensated by this adjustment.


3"x10" hydraulic cylinders
A
A
Adjustable positive stops
Split rack transmits cylinder thrust to rotate fixture
Dogs bolted in T-slots on fixture
Locating surface of aircraft piston
Micro Switches and limit switches mounted inside housing, actuated by plungers
Section A-A from Front

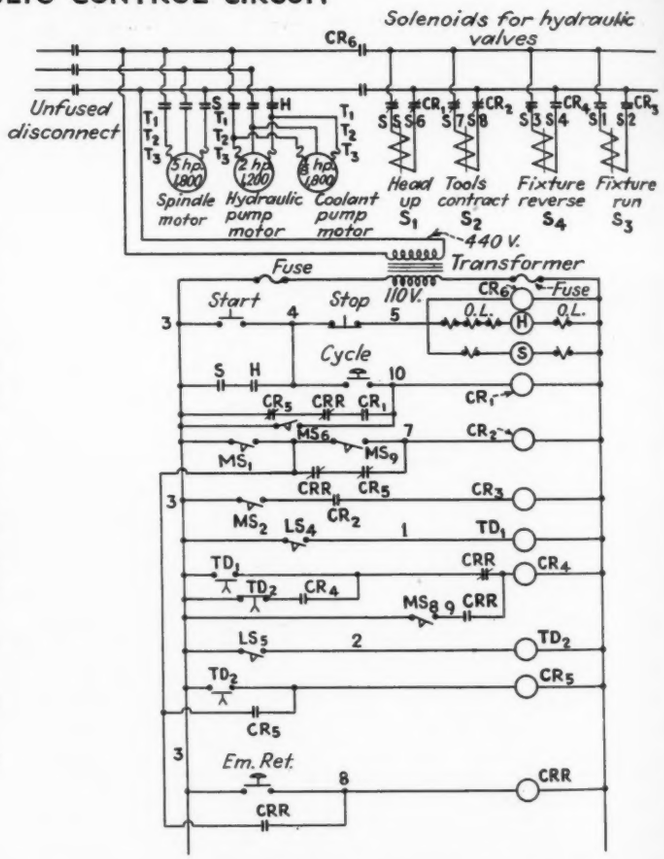
DETAILS OF ROTARY TABLE AND CAM-OPERATED FIXTURE

(Continued on next page)

HYDRAULIC FIN MILLING MACHINE (continued)



HYDRAULIC CONTROL CIRCUIT



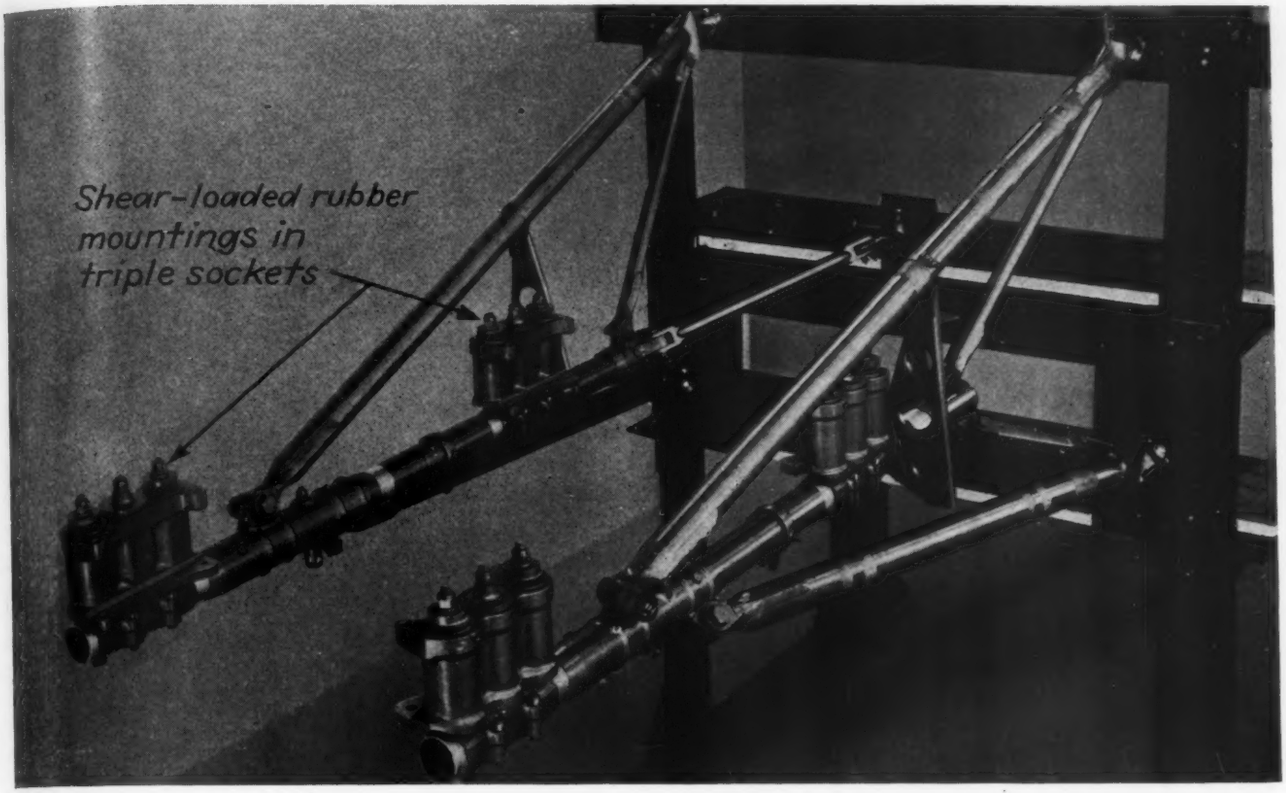
ELECTRICAL CONTROL CIRCUIT

OPERATION

1. Spindle slide cylinders and head cylinder held in starting position. Table cylinders at mid-position.
2. Solenoid valve S_1 de-energized by start button, and head rapid-advances hydraulically to solid stop, trips Micro Switch MS_1, and holds.
3. Solenoid valve S_2, de-energized, and 2x3 in. cylinders feed to expand spindle slides to solid stop, tripping Micro Switch MS_2.
4. Solenoid valve S_3 energized, and fixture rotates forward from center to solid stop.
5. Solenoid valve S_4 energized and fixture reverses past center position to solid stop.
6. Solenoid valve S_4 de-energized, and fixture returns to center position. Stops at exact center position.
7. De-energize S_3 at center position so that fixture stops at exact center.
8. Solenoid valve S_2 energized to contract tool slides and hold.
9. Solenoid valve S_1 energized to retract head.
10. Emergency return is in sequence.

Interlocked hydraulic and electric circuits operate the machine cycle automatically. When machine is started from push-button station, it follows through lowering and expanding of spindles, table feed forward and reverse through complete cutting cycle, and spindles then contract and withdraw upward to starting point. Hydraulic pump is driven by 2-hp. motor. Piping and pump are contained within oil tank. Valves and speed control meters are externally mounted for quick adjustment. Elements of electrical circuit are compact.

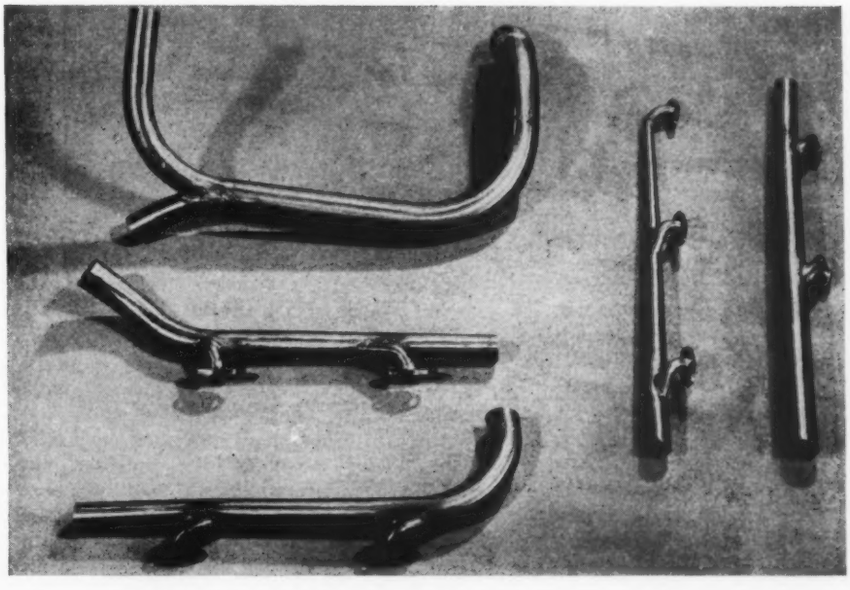
AIRCRAFT ENGINES MOUNTED ON RUBBER



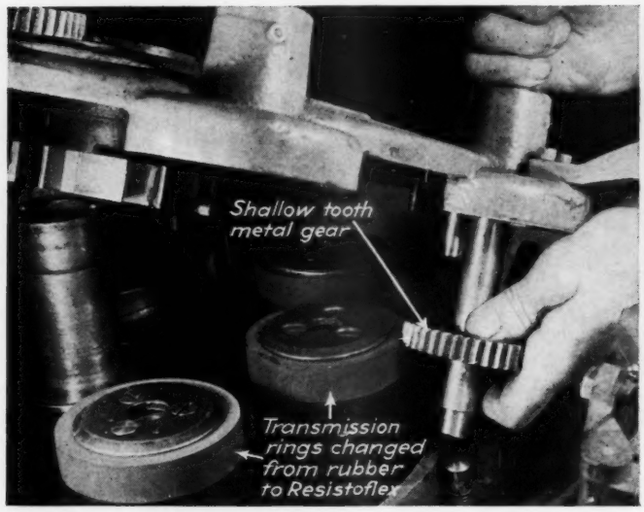
Allison engines in Curtiss P-40 pursuit ships are supported at four points by flexible mountings in order to eliminate effects of vibration. To facilitate overhauls, tubular structure is bolted together and saftied. Each of four motor supports is a group of 3 Lord tube form, shear loaded, bonded rubber mountings in line with main axis of the ship, thus keeping space required to a minimum. Front mountings are of stiffer composition than rear mountings, taking advantage of resilience of tubular structure, and relieving engine of torsional strain. No resonance points occur in range of engine speeds, and vibrations of power impulses are absorbed by rubber in shear. (P.E., Feb. 1942, pages 62-67.) Horizontal restraint of tube type mountings gives "cross-member" stability. Vertical motion of engine is limited by separate snubbing washers which supplement functions of the mountings.

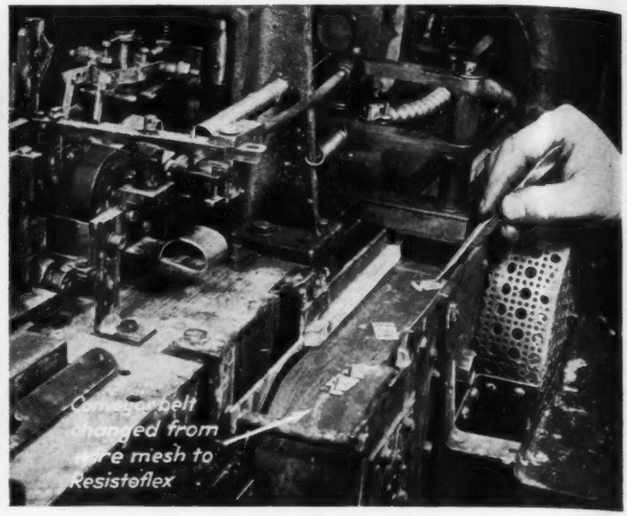
WELDING SPEEDS FORMING OF 18-8 COOLANT SYSTEM

Design study of coolant system for recently designed liquid-cooled aircraft engine showed several ways to speed production. Parts are formed from 18-8 stainless steel welded tubing, chosen for strength, corrosion resistance. Trouble was encountered in welding finish-machined flanges to tubes; distortion hindered assembly to engine. Semi-finished flanges are now welded on; finish machining is done after part cools. Some pieces involved a bend in one plane interlocked with a bend in another plane—impossible as a forming operation unless with drop die. By bending two sections of tube and then welding them together, shape was more easily achieved. Further redesign may avoid weld. Some outlets, of 18-8 welded tubes with 0.032-in. wall thickness, are successfully bent to $\frac{5}{8}$-in. radius.



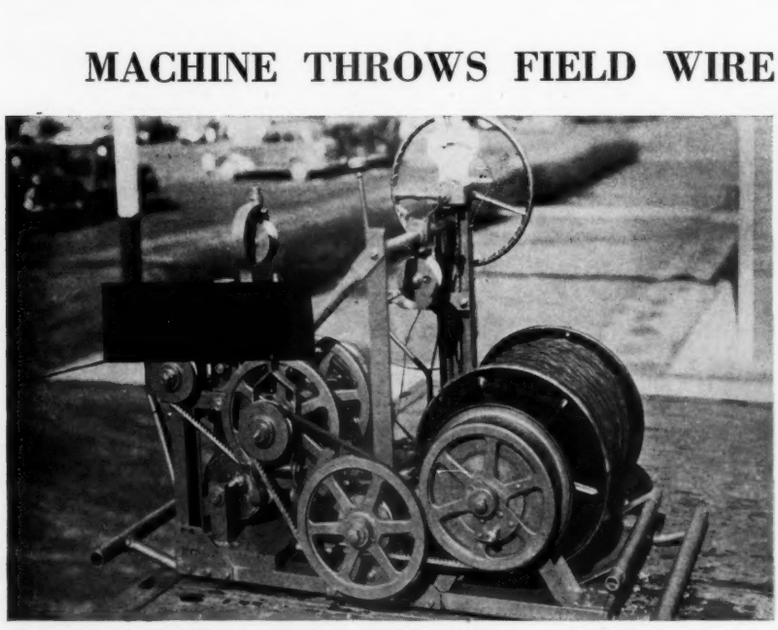
Wartime Designs—SYNTHETIC RESIN REPLACES RUBBER

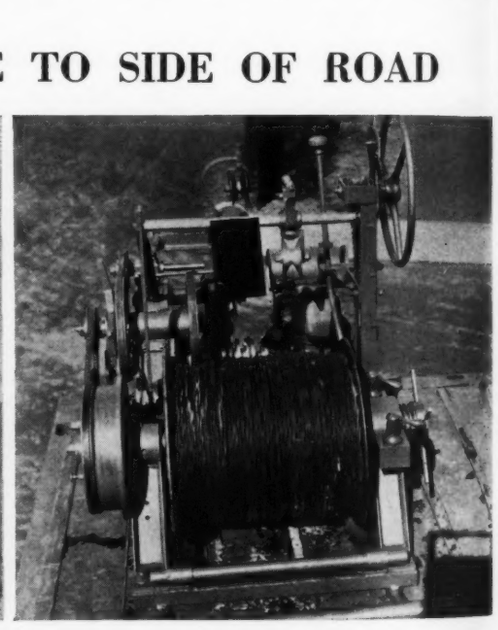




Rubber conservation program at R.C.A. Manufacturing Company, begun when first whispers of rubber scarcities were heard, has led to adoption of Resistoflex (polyvinyl alcohol) synthetic resin in many applications. Typical are transmission rings (left) and conveyor belt (right). In transmission device, revolving turret carries a series of heads, which are revolved in sequence of indexed positions. Heads rotate when their shallow-toothed metal drive gears are brought into mesh with rubber rings clamped to driven shafts. New polyvinyl alcohol rings are reported to outlast rubber rings. In conveyor belt on machine making small parts at R.C.A., the Resistoflex replaces a woven wire belt. Another application is in tubing, where the synthetic resin replaces rubber, brass, copper, and stainless steel.

MACHINE THROWS FIELD WIRE TO SIDE OF ROAD





Insulated field telephone wire can be thrown off to the side of the road from a truck traveling at any speed up to 30 m.p.h. by this Signal Corps wire throwing machine. The wire can be thrown far enough off the road so that it will be free from danger of crushing by other vehicles, and can be projected to height of 40 ft. in order to clear other vehicles or roadside obstacles. The machine consists of steel frame on which is mounted reel cradle, wire-ejecting mechanism, wire recovering mechanism, power unit, driving mechanism, and control mechanism. It is powered by special 5-hp. aircooled gasoline engine connected through automatic centrifugal clutch. Automatic brake is provided for stopping rotation of wire reel and a hand throttle controls speed of engine. Entire unit is mounted on back of 2½-ton truck.

To operate, a reel carrying a mile of telephone wire is inserted in a cradle. Wire is then threaded through a tension and guide pulley. From there it is inserted through rollers and passes through a fin which controls the direction in which the wire is projected. It is possible to control the path of the wire as the truck moves along the road. This is done by adjusting the angle of the ejector. Signal Corps officers believe this design is superior to enemy's, hence withhold further details. By use of this wire thrower, a mile of telephone wire can be laid in two min. by a crew of 3 men. Two trucks acting as a team can lay 50 miles of wire without stopping; one reloads as the other works. The unit is also used to recover wire at any speed up to 10 m.p.h.

WARTIME DEVELOPMENTS

Zinc and lead ore which formerly was lost to the war effort is being recovered in huge quantities by means of instruments which the U.S. Bureau of Mines has developed to show which pillars may safely be removed from old workings.

Thousands of tons of these ores already have been recovered from a worked-out mine in the Tri-State district of Missouri, Kansas and Oklahoma. The device also can be applied to open-stope operations in fields producing iron, copper and other ores.

The instruments amplify and record subaudible noises which precede rock bursts, and study of their graphic recordings taken over appropriate periods allows engineers to estimate whether pressure on a pillar is sufficiently small to allow reclamation. The noises, which are amplified up to 10 million times, indicate pressure zones in the rock and warn of impending falls. Proper use of the instruments not only affords relative safety to the miners but also protects surface installations from subsidence.

Mobile maintenance and repair shops which are capable of handling all but the heaviest jobs in the field will soon be available to Engineer outfits throughout the army. The nine types of trucks which will be used will carry small generators to power tools and lighting systems, small air compressors, portable forges and basic repair shop tools.

Blackouts won't hamper these units, which are equipped with canvas-covered steel frames which close up tight for blackout work or which spread wide to provide a spacious sheltered area. Sides may be lowered to form outside work benches.

The units were developed by the Engineer Board at Fort Belvoir, Va., and were tested in the Carolina maneuvers last fall.

Artillerymen soon will be using cartridge cases of pressed steel rather than brass, and the Army says the changeover not only will save critical materials but will cut costs and lower production time as well.

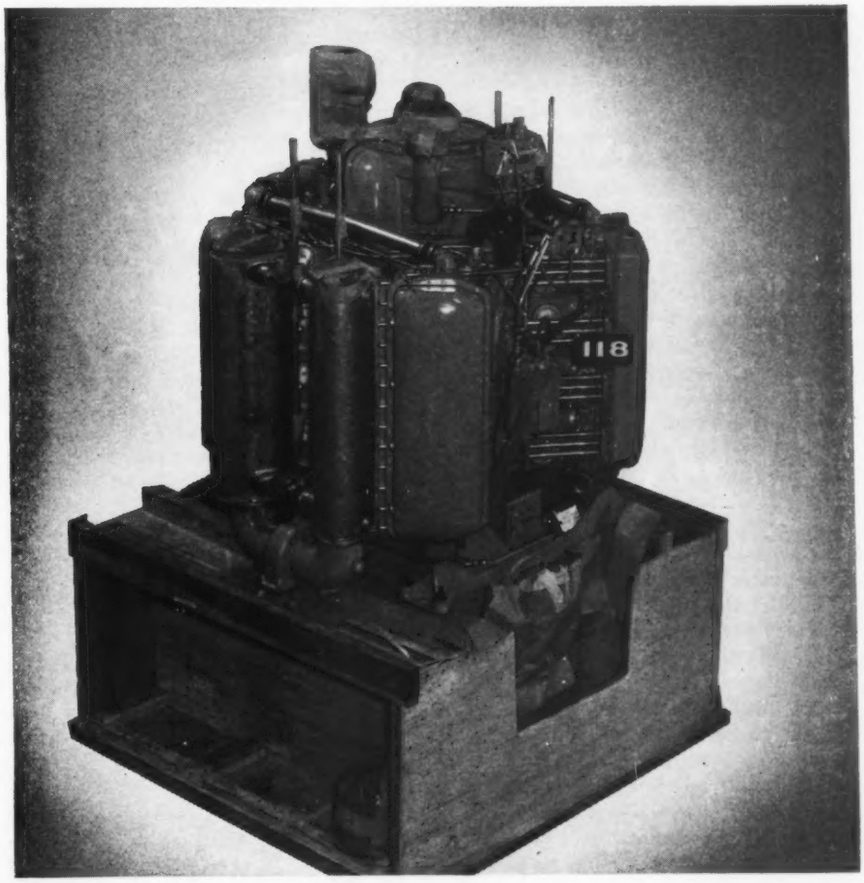
The War Department announced that the switch will be made "within the next few months" after several development orders, announced early this year, proved successful. Meantime, similar experiments in use of steel for small-arms cartridge cases are continuing, following "preliminary good results." Now, such cases are made largely of copper.

Time savings that may be obtained by the substitution of pressed steel for earlier steel models result principally from eliminating processes which formerly called for forging, casting and automatic screw machine operations. The new process will bring facilities of automobile companies and manufacturers of consumer durable goods more completely into the arms program.

Microfilming of old records is saving the army much floor space and many filing facilities. After 100 tons of old Engineer Corps records, which filled 1,000 filing cabinets, had been photographed and the films stored in much less space, the Army set to work on all muster rolls and rosters of the 26-year period from 1912 to 1938. These files now cover approximately 4,000 sq. ft. of floor space, but they will use only two cabinets when reduced to film. The process also conserves metal, officers say.

A new agency to oversee research in at least five fields bound up with the war effort is planned by the War Production Board, which so far has been unable to find the $100,000,000 required to finance it.

Already known as the Office of Technical Development, the proposed agency will neither serve as a catch-all for everybody's ideas on war production nor encroach on governmental or private investigations already under way. In-



New diesel "pancake" engine which is adding cruising radius, speed and maneuverability to the Navy's subchasers charged with cleaning up the coastlines. Two of these power plants, built by General Motors Electro-Motive Division and believed to be the lightest ocean-duty diesels in the world, are installed in newer subchasers. Resultant space and weight savings allow improved performance in range, armament or speed, but newer boats are getting a combination of these gains. For full description, see P. E., Aug. 1942, p. 477.

stead, the WPB pictures it as a body of top-flight scientists and engineers under which promising ideas can be nursed along to the blueprint stage, developed in laboratories, tried out in government-financed pilot plants and finally put into production.

The OTD's field, not yet definite, probably will include rubber, drugs, natural resources, transportation, food.

Despite a slump in June, United States' war production for the first half of 1942 showed imposing gains over 1941 totals. Chairman Donald M. Nelson, of the War Production Board, issued figures showing that aircraft production for the first six months of this year was greater than that during the entire preceding year. Delivered merchant ship tonnage was well more than twice that of 1941, and tank production was more than 3½ times ahead of that for the previous 12 months. Artillery and anti-tank gun production stood at 2,000 a month, and machine guns and sub-machine guns respectively were turned out at rates of 50,000 and 55,000 a month. Despite the figures, Nelson warned that the report should not be the basis for undue optimism.

The spectacular method by which the Luftwaffe dumped an invasion army into Crete from a skyful of gliders is a special expedient for special cases, in the opinion of the War Production Board's cargo plane committee. In support of its conclusion that gliders do not now appear to have any important contribution to make to the general problem of efficient cargo movement on a large scale and over long distances, the committee pointed out that it would require seven or eight cargo planes each towing one or two gliders to move the same amount which 10 similar cargo planes could handle if unencumbered by gliders.

The committee turned thumbs down on the motorless craft in a report to WPB Chief Donald M. Nelson. It recommended doubling of the present cargo plane production program, further impetus to development of long-range land and sea planes and a large increase in facilities for manufacture and transportation of aviation gasoline. Nelson explained that the report would have to be considered in the light of existing plane production efforts, and warned that any broad increase in freight plane production would be at the expense of trainer or fighting plane output. Meanwhile, the WPB is pressing its investigation of possibilities of new production facilities and of conversion of other industries.

The committee showed no overwhelming enthusiasm for air transport's ability to master the export-import situation confronting the United States as Arsenal of Democracy. While it found that as much as 50 percent of the overseas shipments bound for army or navy units are susceptible to shipment by cargo planes, the committee found that probably no more than 20 percent of the non-military exports which must move out of the country during the next 12 months can go by air. In addition, the committee noted, if all expectable production of cargo planes for 1942 and 1943 were immediately available for 2,000 hours in the air yearly, we would still be unable to move into the United States all the supplies of 37 vital commodities which this country must import this year.

Principal types of army craft now under construction as transports include the Douglas C-47 and C-54, the Curtis C-46 "Commando," and the Consolidated B-24, a converted bomber.

The Navy has successfully adapted for cargo work its Martin PBM-3 patrol bomber. It is converting some PB2Y four-motored flying boats, and those tests already completed indicate that the Martin SRM-1 "Mars" will make a fine freighter.

"Safety audits" of munitions plants and other factories in which the explosion hazard exists are becoming routine for the Army Ordnance Department's Explosive Safety Branch. Under the new program, which is administered from Chicago, inspectors study protective measures in force at each plant, after which corrections are agreed upon in conference.

The new agency's planning and reports section is drawing up disaster-relief programs for each plant under its jurisdiction. Individual plans are required by variations in protective measures employed.

Isolating Impact Vibrations In Machinery Foundations — II

LEON M. DEKANSKI
Mechanical Engineer

Development and analysis of a method for calculating the maximum displacement of a foundation under a machine that is subjected to single and repeated impact. Also the procedure for determining load on the energy dampening element and the reaction of the ground.

AFTER the engineer has established such factors as the spring constant k, working values for static and dynamic moduli of elasticity E_s and E_d, and the damping capacity ψ of the isolating material, and also the magnitude of the disturbing force in the system, all as explained in Part I of this article in the August issue of PRODUCT ENGINEERING, the motion of the foundation can be calculated. This motion can be obtained from the familiar homogeneous differential equation with constant coefficients, in which

M = the vibrating mass
c = the friction coefficient
k = the spring constant
t = time
x = the linear displacement of the mass from its initial position at time t sec. after impact

$$M\frac{d^2x}{dt^2} + c\frac{dx}{dt} + kx = 0 \qquad (10)$$

which divided by M becomes

$$\frac{d^2x}{dt^2} + 2n\frac{dx}{dt} + p^2x = 0 \qquad (11)$$

in which the natural frequency p of undamped system equals $\sqrt{k/M}$, and

$n = \frac{c}{2M} = Dp$ where D is the quantity characterizing the damping properties of a given system.

The general solution of Equation (11) for a periodic case is

$$x = e^{-nt}\frac{V_o}{p_1}\sin(p_1 t)$$

$$= \frac{V_o}{p_1}e^{-pDt}\sin\left(pt\sqrt{1-D^2}\right) = \frac{V_o}{p_1}e^{z}\sin(p_1 t) \qquad (12)$$

in which z, the exponent of the Napierian base e, equals

$$D\,p_1 t/\sqrt{1-D^2}$$

In Equation (12) V_o is the initial velocity of M from Equation (9), (August, P.E.), introduced as initial condition for time t equal to zero at which time also the displacement x equals zero. (This treatment of the vibration starting with velocity V_o is permissible only with the assumption that the duration of the impact is so short that the whole impact process is practically over before the response of the vibratory system sets in). The natural frequency p_1 of the damped vibration is

$$p_1 = p\sqrt{1-D^2}$$

The graph of Equation (12) is shown in Fig. 8(a) and the corresponding rotating vector in Fig. 8(b). Incidentally it will be seen from these figures that on the strength of the assumed law of friction the vibration will carry on indefinitely after the hammer impact. However, this does not happen, since in the actual structures there is present in addition to the viscous friction, a certain amount of Coulomb friction which will cause the oscillatory motion to subside completely within a finite time.

The force transmitted to the ground, which is the real measure of effectiveness of the isolation, is found from Equation (10) which can also be written

$$-M\frac{d^2x}{dt^2} = c\frac{dx}{dt} + kx \qquad (13)$$

which means that the inertia of the foundation is equal to the sum of friction and spring forces.

The velocity V of the mass M at any instant or dx/dt is found by derivation

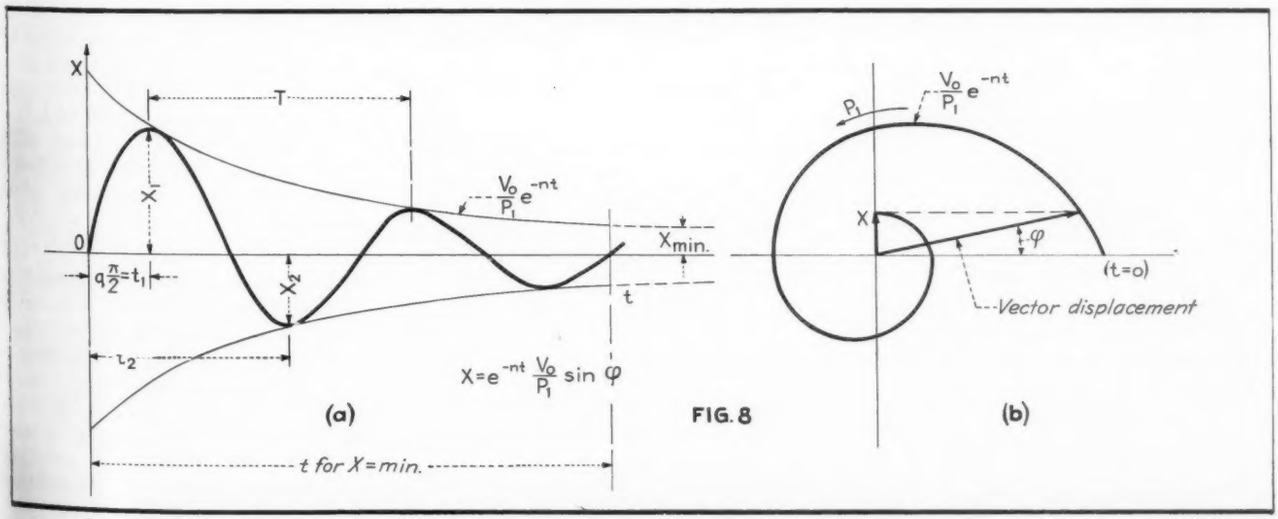


Fig. 8—(a) Graph of equation for a periodic case showing displacement. (b) Corresponding rotating vector and displacement

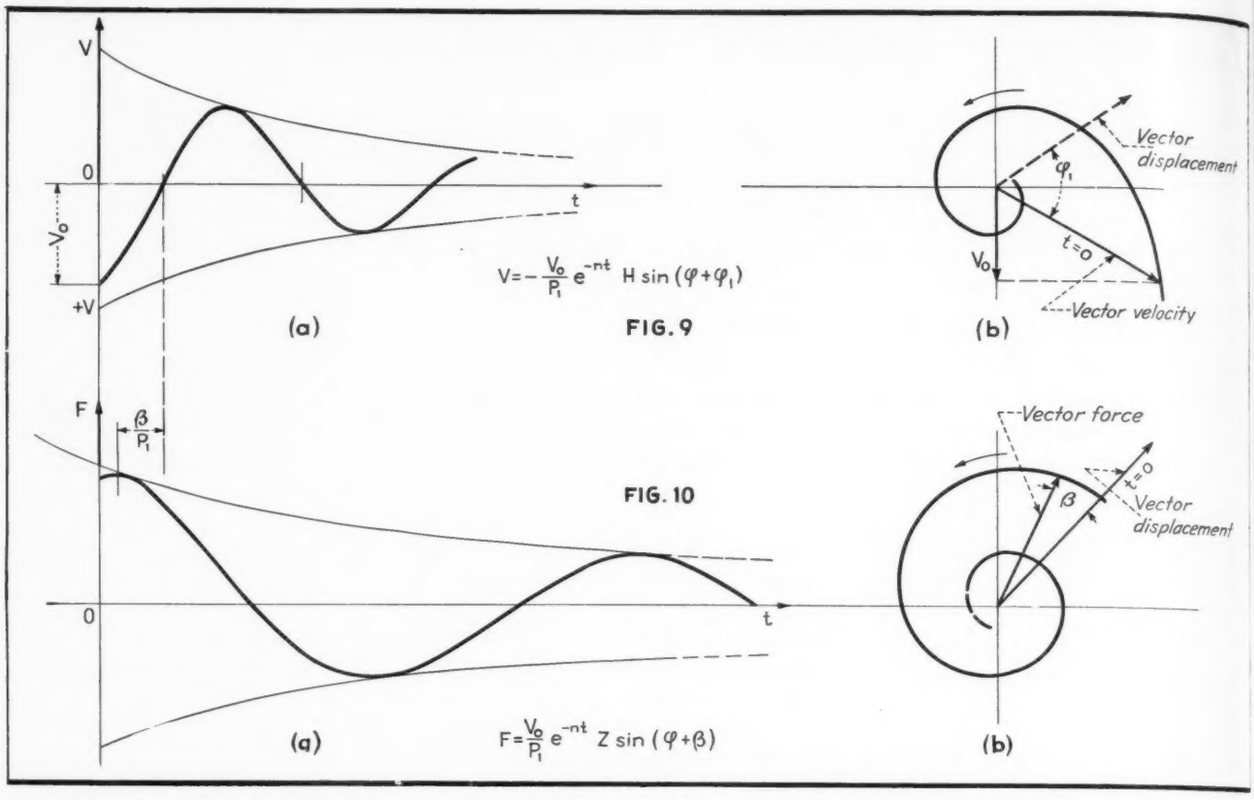


Fig. 9—Graphs of the velocity Equation (14). Fig. 10—Graphs of the force Equation (17) showing force transmitted to the ground

of Equation (12) in respect to time where

$$\varphi = p_1 t, \quad \tan\varphi_1 = p_1/n,$$
$$\text{and } H^2 = 1/(p_1^2 + n^2)$$

$$V = \frac{V_o}{p_1} e^{-nt}(p_1\cos\varphi - n\sin\varphi)$$

$$= -\frac{V_o}{p_1} e^{-nt} H\sin(\varphi + \varphi_1) \qquad (14)$$

The graph of Equation (14) is shown in Figs. 9(*a*) and (*b*), from which it will be seen that the displacement x and the velocity dx/dt are out of phase by the angle φ_1. Introducing the values of x and dx/dt in Equation (13) and introducing for brevity the factor

$$A = \frac{V_o}{p_1} e^{-nt}$$

an expression for the load on the spring F_s can be obtained

$$F_s = k\,A\sin\varphi \qquad (15)$$

in a similar way the friction force F_f of the system is found to be

$$F_f = c\,A\,H\sin(\varphi + \varphi_1) \qquad (16)$$

Combining Equations (15) and (16) with the usual vector technique, the total force F transmitted to the ground is found to be

$$F = A\,Z\sin(\varphi + \beta) \qquad (17)$$

$$\text{where } Z = \sqrt{(c\,p_1)^2 + (k - cn)^2} = k \qquad (18)$$

$$\text{and } \tan\beta = \frac{cp_1}{k - Cn}$$

$$= 2\,D\sqrt{1 - D^2}\,(1 - 2\,D^2) \qquad (19)$$

Upon substituting these values Equation (17) becomes

$$F = \frac{V_o\,p\,M}{\sqrt{1 - D^2}} e^{-nt}\sin(\varphi + \beta) \qquad (20)$$

The graph of Equation (17) is plotted in Figs. 10 (*a*) and (*b*).

If it is assumed from the symmetry of the curve that t_1 equals $T/2$ (this assumption becomes less accurate as the damping D increases, for example, for D equal to 0.35 the error is minus 4½ percent) the value of t_m corresponding to the maximum of F may be determined from the consideration that for such condition the term

$$\sin(\varphi + \beta)$$

must acquire its maximum value equal 1, hence

$$\sin(p_1 t + \beta) = 1, \text{ from which} \qquad (21)$$

$$t_m = \frac{1}{p_1}\left(\frac{\pi}{2} - \beta\right) \qquad (22)$$

Upon substituting t_m in Equation (20) the maximum value of transmitted force is obtained

$$F_m = \frac{k\,V_o}{p_1} e^{-n/p_1} \qquad (23)$$

Remembering that

$$p_1 = p\sqrt{1 - D^2} \text{ or for brevity } p\,\theta$$

Equation (23) may also be written

$$F_m = V_0 pM\frac{1}{\theta} e^{-(D/\theta)(\pi/2 - \beta)} \qquad (24)$$

It is of immediate interest to compare the transmitted force F_m of the damped with that of the undamped foundation F_u for which

$$F_u = V_0 pM$$

therefore the required ratio is

$$\frac{F_m}{F_u} = \frac{1}{\theta} e^{-(D/\theta)(\pi/2 - \beta)} \qquad (25)$$

The plot of Equation (26) is shown in Fig. 11 from which it will be seen that the function F_m/F_u has a minimum value corresponding very closely to D equal to 0.35. This important result shows that by introducing a proper damping, a decrease of transmitted force of over 20 percent can be obtained for the same weight of the foundation. It will be seen further that damping values of D up to 0.6 are favorable, while dampings greater than 0.6 would definitely be harmful.

Remembering that D equals $c/2Mp$ and equating this value to 0.35 it is found that the corresponding friction coefficient

$$c = 0.7\,M\,p \qquad (27)$$

This relation is of fundamental importance since it provides the means for designing the damping device. From a practical point of view, the damping device (for example, the dashpot) is usually provided with adjustment so that the amount of damping can be varied when the installation is completed, and experiments carried out to determine the optimum conditions.

The maximum value of the force

transmitted to the ground during the first quarter period after the hammer impact is found by substituting in Equation (24) the optimum damping value of D equal to 0.35

$$F_m = 0.762\, k \frac{V_0}{p_1} \qquad (28)$$

Equation (28), therefore, represents the maximum force "escaping" through a foundation of minimum weight.

Calculation of the Maximum Displacement

With reference to Fig. 8(a) the first positive max. of x will occur at

$$\varphi_1 = p_1 t_1 = q \frac{\pi}{2}$$

where q is a correction factor necessary to take into account the non-symmetry of the curve. For D equal to 0.35 and q equal to 0.78

$$\varphi_1 = 0.78 \frac{\pi}{2} = 1.23$$

Upon substitution of φ_1, in Equation (12)

$$x_1 = \frac{V_0}{p_1} e^{-1.23 D/\theta} \sin 1.23 \qquad (29)$$

For $D = 0.35$ and $D/\theta = 0.374$

$$x_1 = \frac{V_0}{p_1} e^{-0.45} \sin 1.23 = \frac{V_0}{p_1} (0.59) \qquad (30)$$

In a similar way the max. upswing amplitude x_2 for

$$\varphi_2 = \varphi_1 + \pi$$

is obtained as

$$x_2 = \frac{V_0}{p_1} (0.184) \qquad (31)$$

In addition to these relations, there is another condition that must be satisfied; namely, that at no time should the resilient element be completely unloaded. The necessity of this condition is obvious when resilient elements which cannot work in extension are used. To realize this condition the max. negative amplitude x_2 must be less than the static deflection S of the resilient element. With reference to Fig. 8 (a), x_2 is less than S, or with a safety margin S_0, so that

$$\epsilon = (1 + S_0/S)$$

then

$$x_2 \leq S\epsilon \qquad (32)$$

Remembering that

$$S = \frac{Mg}{k} \text{ then } x \leq \frac{Mg}{k} \epsilon$$

Normally, with reasonable damping and not too hard springs, this condition is never reached. However, for check calculation, the Equation (32) can be brought in a more suitable form by substitution of x_2 from Equation (31).

$$0.184 \frac{V_0}{p_1} \leq \frac{Mg}{k} \epsilon$$

And since $k/M = p^2$

$$p \leq \frac{g\epsilon\theta}{0.184\, V_0}$$

Load on the Springs

With reference to Fig. 12 it will be seen that if the line OA represents the "characteristics" of the spring, so that

$$SK = S \tan \alpha = F$$

then OS_1 represents the static deflection and $S_1\, S_2$ the additional dynamic deflection. Therefore the maximum total deflection is

$$\frac{Mg}{k} + x_1$$

and the maximum force on the springs

$$F_2 = k\left(\frac{Mg}{k} + x_1\right) = Mg + k\, x_1 \qquad (34)$$

In evaluating the size and cost of the resilient elements an important fact should be borne in mind: The theoretical volume of a given type and shape of resilient element depends exclusively upon the permissible stress and elastic modulus of the elastic medium and is independent of the number of elements in which the resilient medium may be subdivided. This can be proven by considering Fig. 12 from which can be seen that the elastic work capacity A_e is

$$A_e = \frac{k}{2}(S_1 + x_1)^2$$

$$= \frac{k}{2}\left(\frac{Mg}{k} + \frac{V_0}{p_1} e^{-\pi q D/2\theta}\right) \qquad (35)$$

represented by the area OS_2R in Fig. 12.

On the other hand, the work capacity A_s of the elastic medium can be expressed as

$$A_s = \frac{a\sigma^2 V}{E^2} \qquad (36)$$

where σ = max. unitary stress of the elastic medium.

E = dynamic modulus of elasticity of the elastic medium.

V = volume of elastic medium

a = coefficient depending upon form and type of medium

For coil springs $a = 1/4$

Hence, equating Equations (35) and (36) the volume of the spring required is

$$V = \left(\frac{E^2 k}{2a\sigma^2}\right)\left(\frac{Mg}{k} + \frac{V_0}{p_1} e^{-\pi q D/2\theta}\right) \qquad (37)$$

Repeated Impact

In the preceding calculations the effects of a singular impact were investigated and it was assumed that the vibration is practically damped out before a new impact occurs. If this condition be considered necessary, then it will be seen from an examination of Equation (12) that the oscillation amplitude decays together with the increase of the absolute value of the exponent n and the natural frequency of the foundation p_1; on the other hand it has been shown that if the oscillation amplitude increases above its optimum value the transmitted force will also increase. Therefore, if the transmitted force be kept at its minimum, a certain time is necessary for the decaying of vibrations; conversely, if this time is reduced the transmitted force will ipso facto be increased.

In dealing with quick action hammers, the result will be that the condition of single impact, as assumed in the

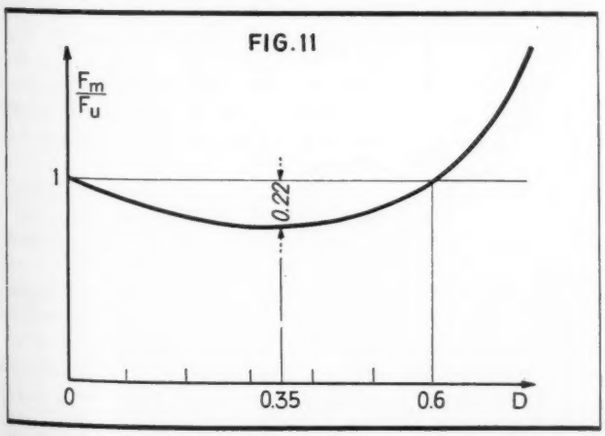


Fig 11—Plot of Equation (26) giving ratios of force transmitted in damped and undamped foundations for various damping

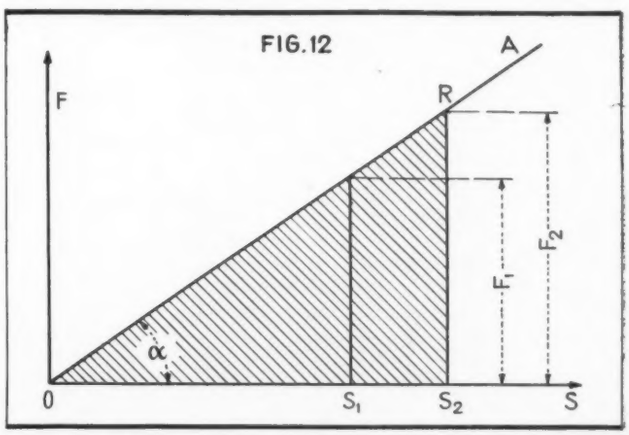


Fig. 12—Relation of spring characteristics, static and dynamic deflections in resilient element

preceding, can hardly be realized in practice, hence the condition will be that of a damped system oscillating under a series of instantaneous impulses. This case cannot be treated by elementary means especially since a considerable damping is used. Although the investigation of such a case is outside the scope of this elementary treatment, one important result from such an investigation should be mentioned, namely that the conditions of resonance of various intensity between the impact frequency q and the natural frequency p_1 of the foundation can occur at many tuning ratios q/p_1. Incidentally this fact represents the essential difference between a quick-acting hammer foundation, and a foundation of a machine with sustained harmonic excitation; in the latter case the resonance in one-degree-of-freedom systems occurs only when the tuning ratio q/p_1 equals one.

Reaction of the Ground

The question of interaction between the foundation and the ground is considerably involved. From a dynamical point of view, the elastic properties of the ground are very complex, and have not been sufficiently investigated up to the present time, at least, not to the extent that could make possible a simple formulation, in a way suitable for comprehensive analytical treatment.

When a portion of the ground under a foundation plate is subjected to shocks or vibrations, the energy is radiated into the ground, partly in the form of oscillations in which a portion of the ground participates, and partly in the form of progressive waves escaping in all directions; often over considerable distances from the point of disturbance. The exact mathematical treatment of this problem would therefore require the consideration of the ground as a continuous elastic medium.

An approximation can be achieved by considering the vibrating portion of the ground as a spring, the mass of which cannot be neglected. This is further complicated by the fact that the mass itself cannot be taken as a constant, as in the case of the usual structural elements. Experiments have shown that the "co-vibrating" mass of the ground increases together with the ratio of dynamic to the static load. And that this ratio takes on asymptotic value, de pending upon the nature of the ground and the dimensions of the sub-foundation structure.

A further simplification can be achieved by viewing the problem not as a single-degree-of-freedom system as has been done in Fig. 1 (August, *P.E.*), but as a two-degree-of-freedom system as shown in Fig. 13. In this arrangement M_1 is the hammer mass plus the foundation mass, M_2 is the portion of the ground mass participating in the oscillating energy exchange of the system including the sub-foundation structure, and G the solid ground. Also k_1 and c_1 represent the elasticity and the damping of the isolating medium, while k_2 and c_2 are the corresponding values for the co-vibrating portion of the ground.

However, without much sacrifice of accuracy, the two masses can be considered as uncoupled during the first quarter of the transient oscillation. This assumption will make it possible to investigate the motion of the mass M_2 under the action of the force F_m found in Equation (23) oscillating with the angular frequency p_1 from Equation (12).

In other words taking M_2, k_2, c_2, and the solid ground as a separate system a corresponding differential equation can be written

$$M_2 \frac{d^2y}{dt^2} + c_2 \frac{dy}{dt} + k_2 y = F_m \sin p_1 t \qquad (38)$$

the complete solution of Equation (38) for small damping c_2 is

$$y = \frac{F_m}{k_2} \frac{1}{1 - r^2} \left[\sin p_1 t - \frac{r}{\sqrt{1 - D^2}} e^{-nt} \sin \omega_1 t \right] \qquad (39)$$

where

$$\omega = \sqrt{\frac{k_2}{M_2}}, \quad \omega_1 = \omega \sqrt{1 - D^2}$$

$$r = \frac{p_1}{\omega_1}, \quad n = \frac{c_2}{2M_2}, \quad D = \frac{n}{\omega}$$

The constants k_2 and c_2 represent the elastic and damping properties of the ground and can be determined experimentally. Some of these constants for various types of ground are given in Table II (August, *P.E.*), where the c values are presented in the form of log decrement for a given frequency.

From Equation (39) the maximum value of y equal to y_m can easily be determined graphically. In a similar manner the maxima of

$$\frac{dy}{dt} = V_g, \text{ and } \frac{d^2y}{dt^2} = A_g \qquad (40)$$

can be found, all occurring during the first quarter cycle.

These values are most important, since, they represent the vertical movement y, the velocity V_g and the acceleration of the ground A_g consequent to the hammer impact, hence they are the only really scientific measure of effectiveness of the isolation.

From this discussion it is easily seen that all of the values y_m, V_g and A_g diminish together with the increase of the foundation weight and with the decrease of the spring stiffness.

Since infinitely heavy foundations cannot be built, the engineer will have to consider the fact that a part of the shock energy is bound to escape the isolation. This fact makes it necessary to establish in an experimental way some kind of standard of "allowable disturbance."

If some permissible standard magnitude is assigned to these values, the corresponding F_m can be immediately found from Equation (39), which together with a similar standard magnitude taken for x_1 as defined by Equation (29) can be introduced in Equations (23), (28), and (30), from which the values of foundation mass M and the elastic constant k can be derived. Thus the problem will be completely determined.

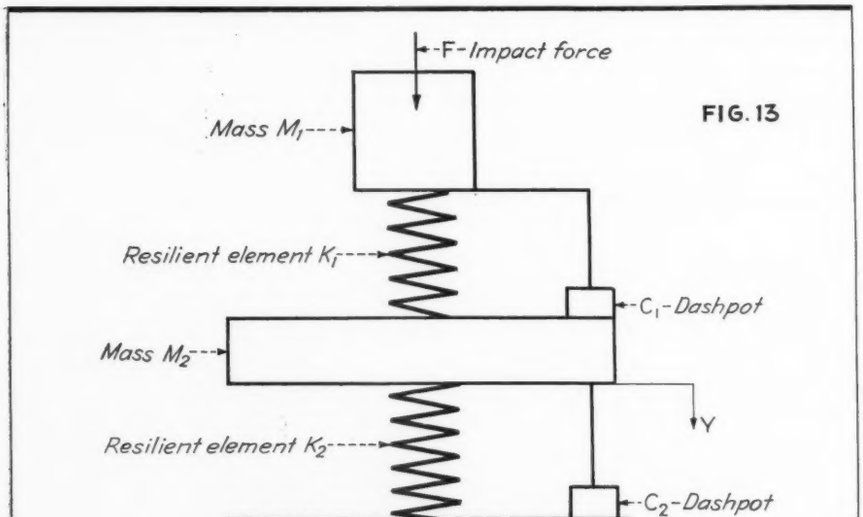
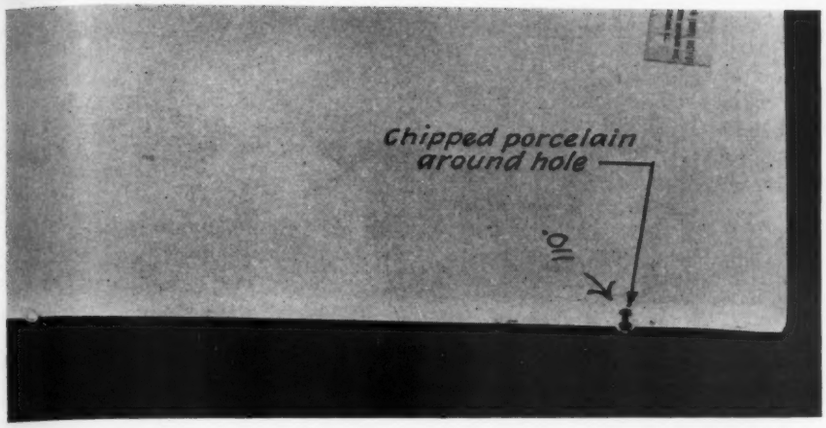


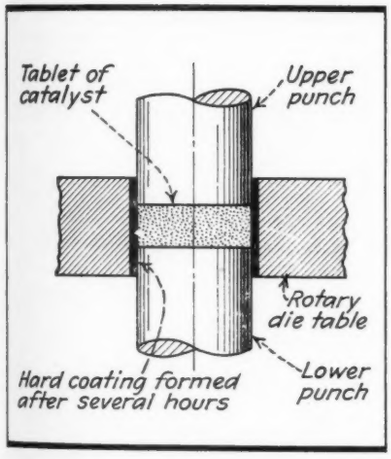
FIG. 13

Fig. 13—Two degree of freedom vibrating system with two dashpot devices for dissipating energy

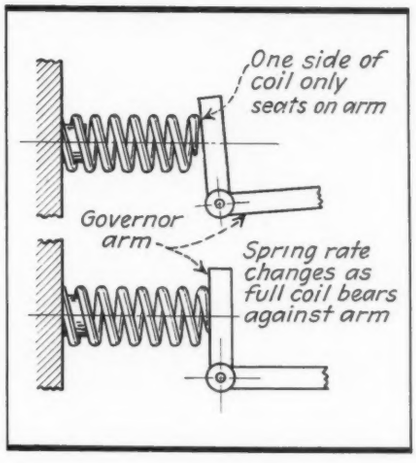
Causes and Cures



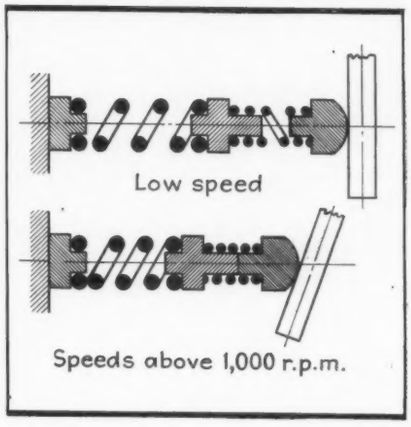
Porcelain enamel of this piece chipped off around hole because hole was placed too close to edge. Strains in assembly or service became excessive. All holes for mounting screws, lugs or mounting brackets should be placed well back from the edges. Holes in this case also should have been edge-brushed, although defect did not result from this cause, to minimize chipping in assembly.



Rotary type tablet forming machine, when placed into production of tablets of a catalytic agent, stalled after a few hours of operation. Cause: a hard metallic oxide coating had formed on the punches and dies. Thickness had reached a few thousandths of an inch, whereupon the punches froze in the dies. Inspection of the coating indicated it would be a satisfactory bearing material so, after cleaning up the punches and dies, the manufacturer simply rebored the dies 0.005 in. larger. Although this large clearance caused irregular tablets for the first few hours, the hard coating soon formed again and reduced the clearance to normal. Operation from that point on remained trouble-free.



Diesel engine governor was not functioning properly at idling speed. The engine surged or "hunted" excessively. Governor was of the flyball type, balanced at idling speed by a spring improperly mounted as shown. When governor arm was down all the way, only one side of the end coil of the spring pressed against the arm. When arm raised slightly, spring seated properly, but the effective load-deflection spring rate was suddenly changed, causing the undesirable hunting. A slight change in the position of the spring permitted it to seat properly on the governor arm throughout the full slow speed range, ending the difficulty. Springs should be checked throughout full range to ensure proper seating.



In a governor of the flyball type, the governor arm was balanced at the set speeds by two springs assembled in combination as shown. The springs were both in effect at idling speed and at low speeds up to 1,000 r.p.m. of the internal combustion engine. But at speeds above 1,000 r.p.m. the spring at right collapsed, whereupon the load-deflection rate of the left-hand spring alone became effective at higher speeds. This design caused considerable undesirable hunting at speeds between 900 and 1,100 r.p.m. at no load. Cause: in this range the right-hand spring easily collapsed with any surge, creating a quick change in the load-deflection rate of the assembly. Cure was to substitute a single spring for the two in combination. Wherever springs are used in sensitive controls, they must be designed and mounted so that no sudden changes in spring rate occur through the range of operation.

A SHEET OF LAMINATED GLASS was required by a recent British design to pass a certain pressure test. Slowly applied air pressure caused an unduly large number to bulge and then break. It was then discovered that the glass which the British had used was bonded with cellulose acetate, which, of course is relatively rigid, while the American glass is bonded with vinyl butyral or other yielding, tough, strongly adhesive plastic. It was only the bonding which made the difference in the strength of the two glasses.

PRODUCT ENGINEERING will pay a minimum of $3 for each example published in Causes and Cures. Where illustrations are necessary, include drawings, rough sketches or photographs.

Testing Small Springs

JOHN F. CAVANAGH

FROM SIMPLE DEVICES up to intricate mechanisms, proper functioning and satisfactory operation frequently depend upon the qualities of the springs included in their design. After load and deflection of a spring have been calculated or experimentally determined, there remains the question as to how long the spring will function. Tests should be made not only as a means for measuring endurance but also to check against variations in temper and alloy characteristics.

Fig. 1 shows a set-up for simultaneously testing two small mechanisms which have hairpin type springs similar to the sample shown on the platen. For this test a block of maple is adjustably mounted upon the reciprocating bar of an old filing machine. For springs designed to carry loads in excess of approximately 5 lb., stronger mechanisms should be provided. The maple block carries a cross bar which engages the two levers which in turn deflect the springs. Springs under test are deflected an amount corresponding to normal operation with each revolution of the crank. A revolution counter is mounted in a convenient manner. Standard electrical devices may be utilized throughout, or contacts and relays may be improvised using equipment on hand.

Two nails are driven into the base board and two pieces of flat spring brass are screwed to the board so that they normally contact the nails. A bell ringing transformer and a door bell are also mounted as shown and are wired up as indicated in Fig. 2. A fine wire or cord is tied between each spring and its corresponding contact spring so as to hold the latter out of contact with the nail. When a spring breaks, the bell rings, the machine is stopped manually, and the number of deflections are recorded.

Frequently it is the "set" rather than actual breakage that is the primary consideration of the design. In such cases the arrangement shown in Fig. 3 will prove satisfactory for small springs, including flat springs. An extension spring or a flat spring to resist pulling action is attached to the end of the screw on the side indicated. This spring is so loaded as to just cause separation of the contact points at the limit of the deflection for which the spring is designed.

As shown on the wiring diagram of Fig. 3, a contact is arranged to be closed by a pin on the pulley of the crankshaft when the reciprocating bar is at the top of the stroke, which point corresponds to the instant when the contact on the rocker is broken by the spring under test. Should the spring under test weaken or set to the extent of not opening the contact on the rocker the instant the pulley-controlled contact is closed, the latch of the relay will be released thus opening the motor circuit and stopping the machine.

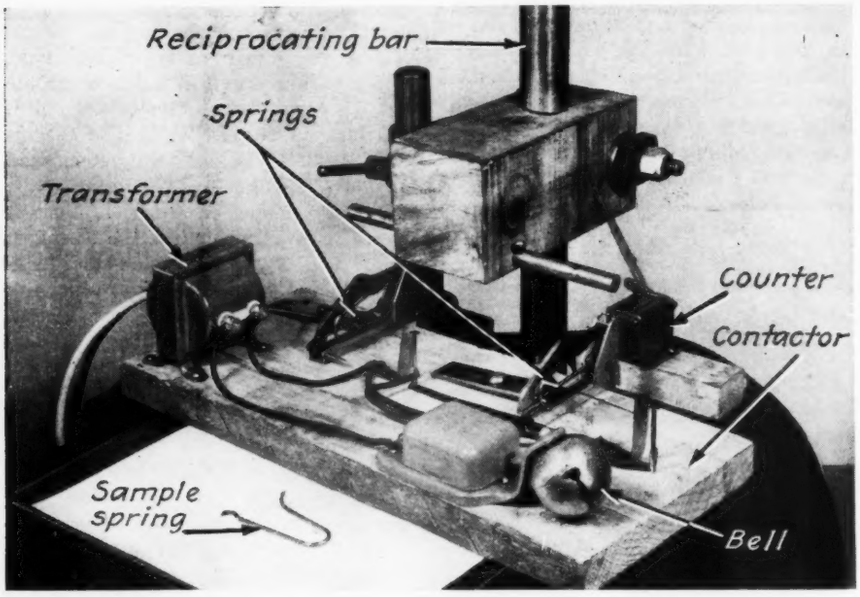


Fig. 1—Discarded filing machine set up for testing endurance of small springs

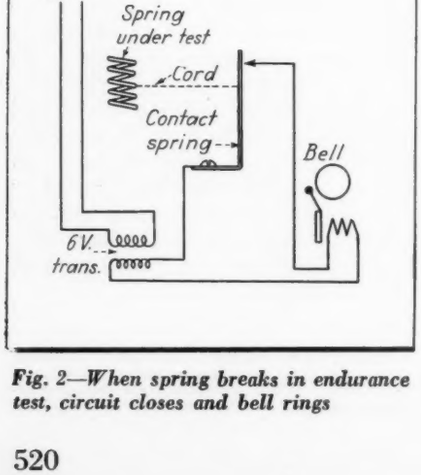


Fig. 2—When spring breaks in endurance test, circuit closes and bell rings

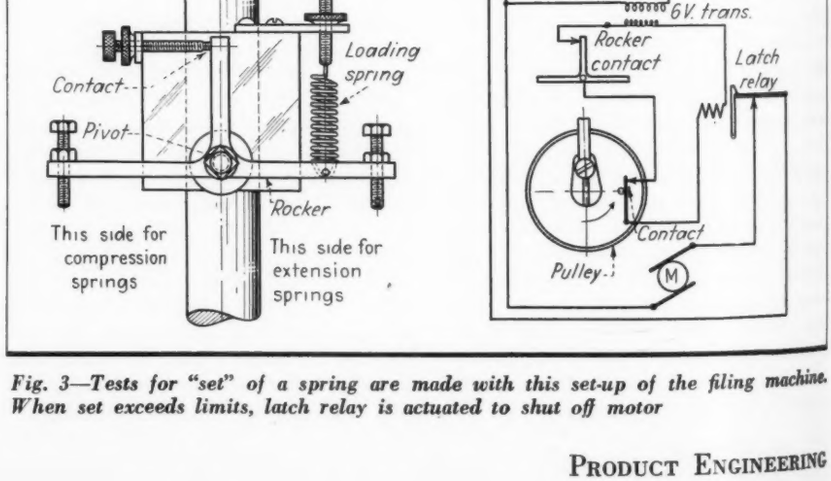
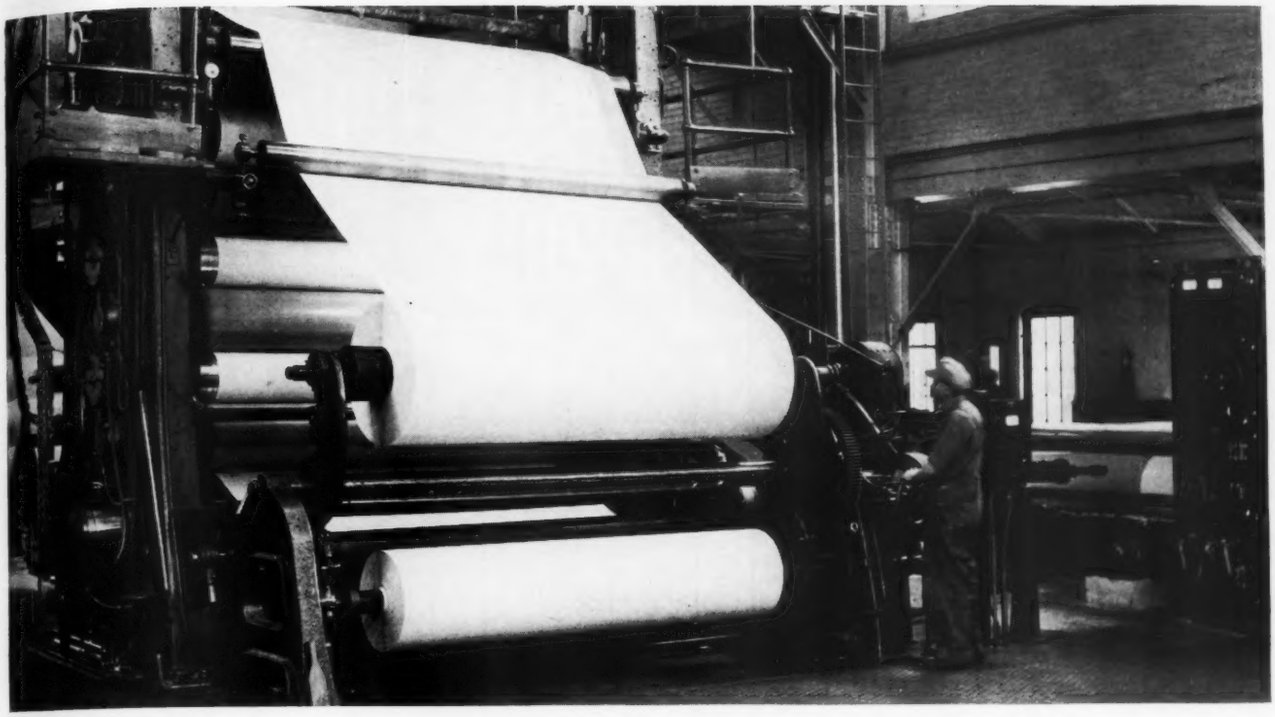


Fig. 3—Tests for "set" of a spring are made with this set-up of the filing machine. When set exceeds limits, latch relay is actuated to shut off motor



Addition of a pilot generator makes possible more accurate performance in the operation of this supercalender in a paper plant

Multi-Field Pilot Generator Gives All-Automatic Motor Regulation

C. W. DRAKE
Manager, General Mill Engineering, Westinghouse Electric & Mfg. Company

Merely the addition of a multi-field pilot generator, properly connected into the circuit of an adjustable voltage motor speed control system, can be made to give exacting control of speed, horsepower, torque or acceleration. Regulation of the motor is inherent in the circuit itself; no relays, rheostat adjustment or devices are used.

FOR MANY APPLICATIONS the characteristics of adjustable-speed motors on constant-voltage circuits, or of constant-speed motors operating on adjustable-voltage control, are satisfactory. However, more and more instances are being found where regulation of characteristics other than speed, such as torque, horsepower, or acceleration, is either essential or desirable.

The operation of a d.c. motor can be controlled only by the adjustment or variation of the armature voltage or current, the field current, or some combination of these. In most applications motor generator sets converting a.c. 3-phase power to d.c. and using the adjustable voltage system of control are employed because of numerous advantages obtained in controlling generator voltage by means of its field current.

Motor generator sets supplying adjustable voltage (formerly called variable voltage) have been used many years for steel mill, paper mill, elevator, reversing planer, and other drives. Their use is now expanding in other industrial applications.

In the adjustable voltage system, the armature voltage and current of a d.c. driving motor are controlled by varying the shunt field current of the d.c. generator that furnishes the current for the motor armature. Because the shunt field current is always low, generally only 1 to 2 percent of the armature current, its regulation is simple and efficient. High-current contactors are not required and power losses in resistors are negligible. These are the main advantages of this system of speed control over the constant voltage system of control wherein high armature currents must be regulated.

In the conventional adjustable voltage system of d.c. motor speed control, the generator field current is usually regulated by the manual or mechanical adjustment of a rheostat. In the improved adjustable voltage system of speed control developed by Westinghouse, a specially designed auxiliary d.c. generator,

which has a number of field windings, is incorporated in the control system. The auxiliary generator, or Rototrol as it is called, is driven at constant speed and automatically regulates the equipment to give the speed, torque, horsepower output or other characteristics desired of the driving motor. The control of the different particular operating characteristics desired are obtained by connecting the field windings of the Rototrol in various manners, as will be explained. The current output of the Rototrol may be used to furnish or to supplement the main generator shunt field current or the motor shunt field current. Thus the Rototrol is a small machine, furnishes only a small amount of power and is frequently assembled as a part of the motor-generator set.

In its simplest form, the Rototrol has three field windings. One is a series field and the other two are shunt fields and are called the pilot field and pattern field, respectively. The pattern field is connected into the circuit of the system so that it determines automatically what the magnitude of the regulated operating characteristic shall be. A rheostat in this circuit permits adjustment of speed, torque, or horsepower as the case may be. Once adjusted for the particular manufacturing conditions, the regulation is automatically maintained at the prescribed value.

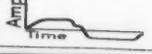
The pilot field of the Rototrol automatically compensates for all changes in operating conditions that tend to cause the magnitude of the speed, torque, horsepower or other operating condition to deviate from that called for by the pattern field rheostat setting.

The current output of the Rototrol is used to furnish or supplement the shunt field current of the d.c. generator or the d.c. driving motor. The d.c. generator may be compound or simply shunt wound. Because the system does not involve the use of vibrating relays, contactors, delicate moving parts or mechanical linkages, it is free of all the troubles associated with such devices. After the initial adjustment has been made, the system requires only the same inspection and maintenance as that required of any d.c. machines.

Complete detailed descriptions of all the possibilities in the application of this control system is not feasible. But the accompanying chart shows and explains four typical arrangements for the control of seven different characteristics or functions of driving motor output. Bearing in mind that increased generator field gives increased voltage while increased motor field results in decreased motor speed, it is relatively simple to analyze the method of operation as presented in the schematic wiring diagrams.

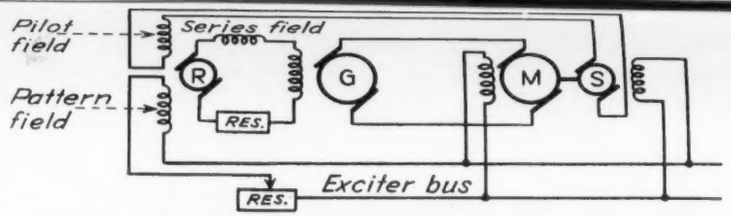
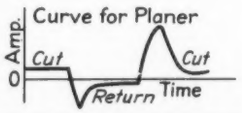
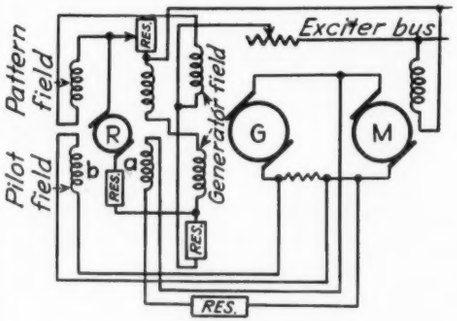
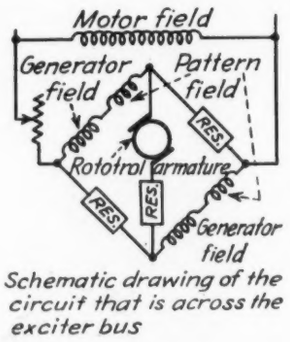
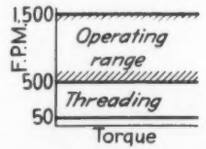
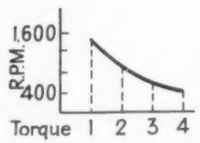
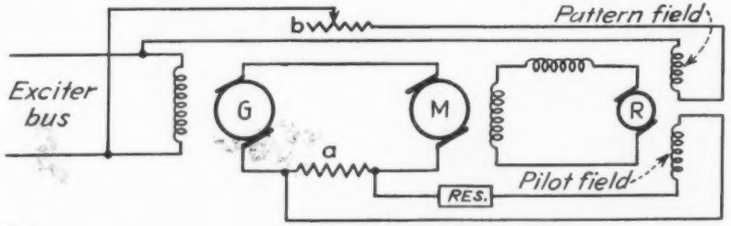
Typical Circuits for Multi-Field Pilot Generator Motor Control

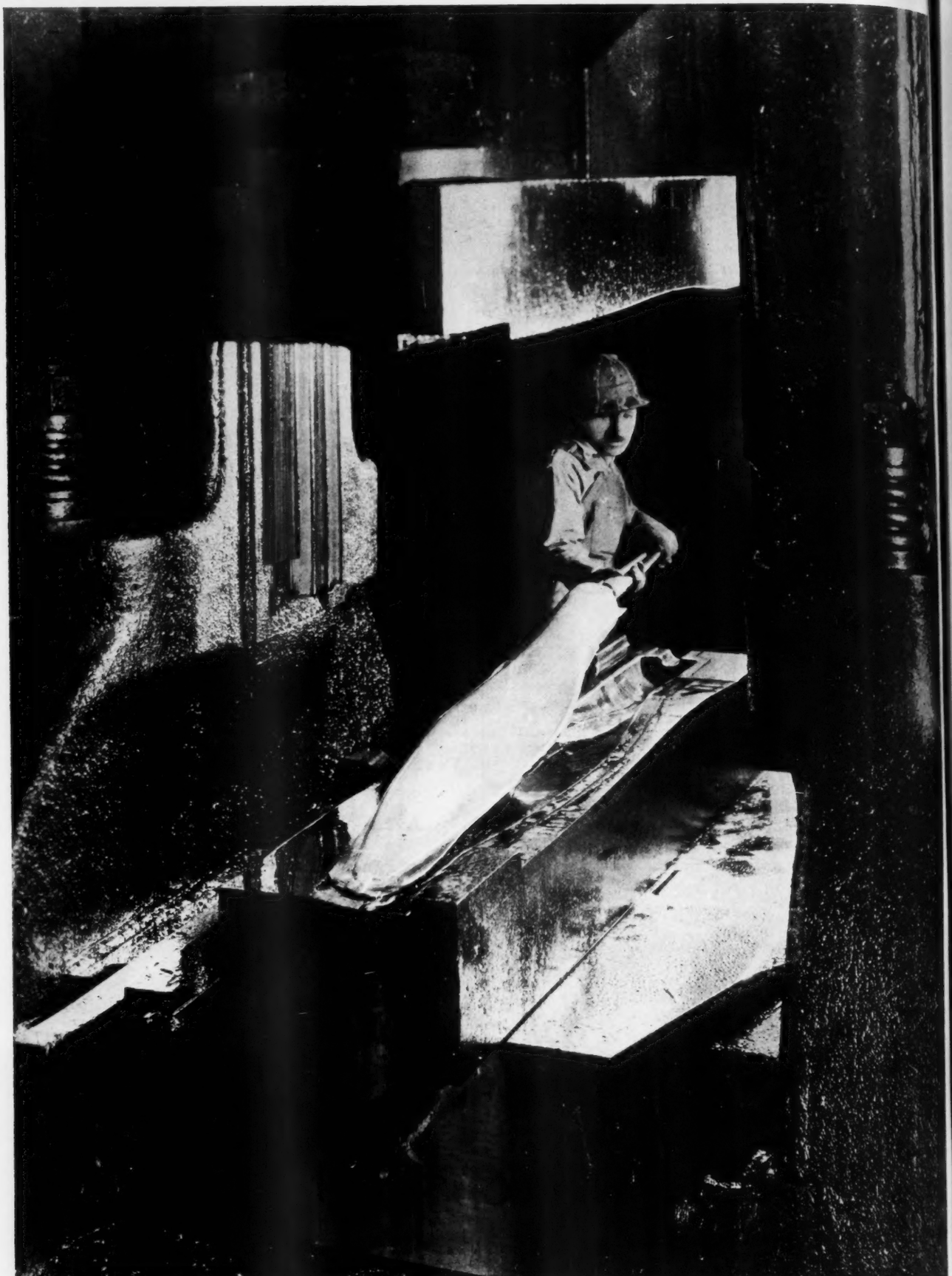
Function	Applications	Characteristic Curve or Performance	Basic Circuit of Regulator and How It Works	Remarks
Uniform acceleration and deceleration by current regulation	Hoists and high inertia loads such as centrifugal machines, flywheels.	Develops constant torque and consequently uniform acceleration at any desired rate.	Current in pilot field is proportional to current of main generator since the field is connected across shunt *(a)* or in many cases simply across a portion of generator windings. On small machines main generator current passes through pilot field. Balanced condition of Rototrol is obtained when pilot and pattern fields neutralize each other. Strength of pattern field can be changed by adjusting rheostat *(b)* for regulating at a different resistance. Constant armature and field current in d.c. motor produces constant torque. In one instance this may produce uniform acceleration while in another it will produce uniform driving effort over a wide speed range. Various modifications of schematic diagram and inter-connection with other control devices are necessary to produce results required for each application.	Maximum possible acceleration may be obtained without current peaks such as occur when using contactors or relays. This reduces commutator maintenance and mechanical stresses.
Constant torque over wide speed range, by current regulation	Wet end or auxiliary drives on paper machines or other helper drives.	Constant torque or driving effort, regardless of speed, over wide speed range determined by main drive.		Applied in conjunction with a main drive where auxiliary motors must deliver constant predetermined torque over a wide speed range.
Torque limiting by current regulation	Electric shovels, draglines, etc.	Controlled accelerating and decelerating and limitation of current or torque peaks, as when plugging.		Reduces mechanical shock on equipment to safe values and thus reduces the maintenance. Controlled acceleration and deceleration gives maximum production.



devices are necessary to produce results required for each application.

celeration and deceleration gives maximum production.

Regulated speed, by voltage regulation	**Single motor paper machine drives and other process machines requiring close speed control.**	**Speed maintained constant within close limits, regardless of load over wide speed range.** 	 Voltage of speed indicating generator *S* is proportional to its speed. Hence speed change causes change in pilot field of Rototrol and thereby change in voltage of main generator *G*, which brings motor back to set speed. Pattern field rheostat adjusts speed to setting desired.	**Used where high degree of speed regulation is desired, as on paper machines for maintaining correct weights. Since same excitation source is used for pattern field and for speed indicator, any normal variation in exciter voltage is automatically compensated.**
Adjustable speed by voltage and current regulation	**Feed drives for machine tools and other similar requirements. Reversing planers and similar machines. Does not stall at low speeds.**	**Close speed regulation of uniform load over wide speed range, as high as 120 to 1, or for speed regulations where rapid reversals, up to 30 to 1, and shock loading occurs.** 	  *Schematic drawing of the circuit that is across the exciter bus* Instead of using a separately excited generator to indicate speed, it is measured indirectly by voltage across motor terminals and by motor current. These two factors are measured by pilot fields *(a)* and *(b)*. In this scheme Rototrol supplies only the regulating power required to maintain constant speed, while normal excitation of generator field is supplied from another source. Under balanced conditions no current is generated in regulator armature. Wider speed range of control with accurate performance is thus possible.	**In drives for feed mechanisms it eliminates many gear changes and simplifies design. Large number of feed speeds, readily available, increases production.** **Reversing drives with planer characteristics are desirable on many reciprocating machines.**
Controlled low speed by voltage and current regulation	**Elevators for accurate landing speeds in either direction. Paper supercalenders — low and definite threading speed regardless of friction or loading. Mine and skip-hoists.**	**Supercalender drive threading speed often 1/30th of max. maintained constant regardless of load.** 		**Accurate threading speed regardless of variation in load enables operators to thread machines with minimum effort and maximum safety. Accurate landing or dumping speeds on hoists are essential for efficient operation.**
Constant horsepower by current regulation	**Core-type winding reels and other winding machines where constant tension on the material being wound is desired or essential.**	**Constant tension in material at a given linear speed requires constant horsepower from motor over entire roll diameter.** 	 When material is received or fed to reel at constant speed, load on d.c. driving motor will increase as reel builds up in diameter. This increase in current is measured by shunt *(a)* and pilot field, which acts to increase strength of motor field and thus reduce motor speed as reel diameter increases. At any linear winding speed remains constant, horsepower developed by the motor is constant over speeds corresponding to the roll diameter. Tension adjustment is obtained by means of rheostat *(b)*.	**Motor speed is maximum at minimum roll diameter, and speed is reduced as roll builds up. Material is supplied from some processing machine which determines the delivery or linear speed of material.**



Aluminum Company of America

WAR ORDERS, such as these aluminum aircraft propeller blanks, are overworking the big forging presses in this country. Careful design of forgings is a "must" for faster, more economical production

Design of Forgings For Speedier Production – I

O. A. WHEELON
Methods Analysis Engineer, Douglas Aircraft Company, Inc.

By keeping draft angles, fillets, edge radii, thin webs and tolerances as large as practicable, design engineers can do much to facilitate procurement, lengthen die life and speed production of forgings badly needed by war industries. In this article are shown the reasons why, and recommendations are given in handbook style for correct proportioning and computation of forging dimensions. Next month: Correct methods for specifying dimensions, tolerances and allowances on forging drawings will be discussed in detail.

IN ORDINARY TIMES the objects of good forging design are to make the best use of the excellent physical properties resulting from high allowable stress, controlled grain flow, ample filleting and absence of porosity in forgings, and to minimize the high die costs inherent in the process by simple straightforward design. This critical period has added a third objective—to facilitate procurement of forgings by designing for highest rate of production per available hammer.

There is every reason to believe that the production and quality of present forging designs can be markedly increased by revising forging dimensions. In a typical case a minor modification in design increased the die life from 37 to 3,000 parts. At a California aluminum forge shop, a capacity of 90 dies per month is devoted to 75 resinks and the balance to new dies. If the limitations of the forging process and the minimum proportions of design details recommended in this article are followed by all product engineers, die life most certainly will be extended, resinks reduced, and production boosted.

Other recommendations for increasing production have to do with die making. By using the limited die-sinking facilities for final operations only, and doing semi-skilled roughing work and templet making in other shops, the skilled die sinker and his machine could operate at maximum efficiency. Also, old die blocks could be reworked, using the die-steel in them to make new dies for prototype forgings in improved designs.

The flexibility of the forging method makes possible a variety of shapes and proportions to meet nearly every need, but limitations of the process make coring out impractical and necessitates generous proportions for filleting, corner radii, webs, and flanges. Accordingly, optimum structural sections are sometimes difficult to attain.

A forging usually starts as a bar or billet, and by a series of hammering operations in various dies it is gradually worked into the desired shape. The exact procedure to be followed is customarily left to the die designer and forge shop. As illustrated in Fig. 1, several distinct steps are used individually or in combination.

FULLERING reduces the cross-section and expands the stock to approximately the required length. The accuracy of distribution of the metal is largely a matter of the hammer operator's ability.

EDGING distributes the volume of metal to more exact requirements. With an edging die the stock is given a rectangular cross-section.

ROLLING is similar to edging, but the resulting piece has a circular cross-section, the die being known as a roller.

BENDING dies are commonly used to alter the axis of the stock before blocking and finishing. Sometimes the bending operation is complicated and may require two or more sets of elaborate dies. Bending operations produce better grain flow in the finished piece.

BLOCKING is next to the last step in the forging process. The blocking die is a rough approximation of the finishing die, and is intended to work the material nearly to shape. The die sections are not driven together. The excess material is squeezed out on the block and sometimes must be trimmed off before the finishing operations.

FINISHING brings the stock to the desired shape and size. The finishing dies are the only dies whose faces are brought together in the forging process. Rather, they are brought nearly together, with a thin fin between them. When parts are extremely simple and

Table I—Common Materials for Forging

14ST Aluminum Alloy	Because of high-strength-weight ratio, recommended for highly stressed parts. Forgings are heat-treated at forge shop but no heat-treatment note required on drawing.
A51ST Aluminum Alloy	Recommended for lightly loaded parts where forgeability rather than high strength is required. Allowable stress only 65 percent of 14ST. Forgings are heat-treated at forge shop but no heat-treatment note required on drawing.
S.A.E. 4135 Steel	Use where space limitations or bearing loads require high-strength material. When heat-treated above 150,000 lb. per sq.in. tensile strength, strength-weight ratio approaches that of 14ST aluminum alloy. Must be normalized and subsequently heat-treated to improve physical properties.
S.A.E. 1020 Steel	May be used as forged (no heat-treatment) for small non-stressed parts or small parts requiring case hardening.
Magnesium X, Z-1 (DOW) AM83S Alloy (AM.Mag.)	Strength-weight ratio similar to 14ST aluminum alloy but allowable stress only 40 percent of 14ST. Because of danger of corrosion, applications must be limited to parts not exposed to severe corrosion. Forgings are heat-treated by forge shop but no heat-treatment note required on the drawing.

Note: Strength of forgings is improved if the direction of grain lies along the axis of greatest stress.

the quantity small, the finishing die may be used for the entire process, the metal being worked gradually by carefully controlled blows.

TRIMMING removes the excess metal which has been forced into the gutter of the die during the finishing operation. This surplus metal appears as a thin web or fin called flash, and is trimmed off by grinding, shearing in a power shear, or shearing with a "cookie" type of die.

There are a number of additional operations which can be performed on the forging blank to make it more nearly meet the requirements of the design, or to reduce the amount of subsequent machining. These operations include bending, twisting, punching-out of webs or bosses, reduction of draft, coining, sizing and planishing. For small forgings one set of die blocks contains all the impressions necessary to carry out the various successive forging steps. Such a die block is called a combination die.

For some forged parts it may be desirable to specify closer dimensional tolerances and smaller radii than recommended in this article. This should only be done when savings in subsequent machining offset the added forging costs, or when subsequent machining may cut too many fibers in the generous fillets, thus weakening the part. Many such examples are shown in the article "Die Forged Parts," by Waldemar Naujoks, published in PRODUCT ENGINEERING for June and July, 1938.

Materials commonly used for forgings include iron, carbon and alloy steel, aluminum alloys, magnesium alloys, brass, Monel metal, copper, nickel and other non-ferrous metals. Specific restrictions and recommendations for applications of the alloys of aluminum, magnesium and steel are given in Table I. Unless otherwise specified, recommended details covered in this article apply to both steel and aluminum forgings.

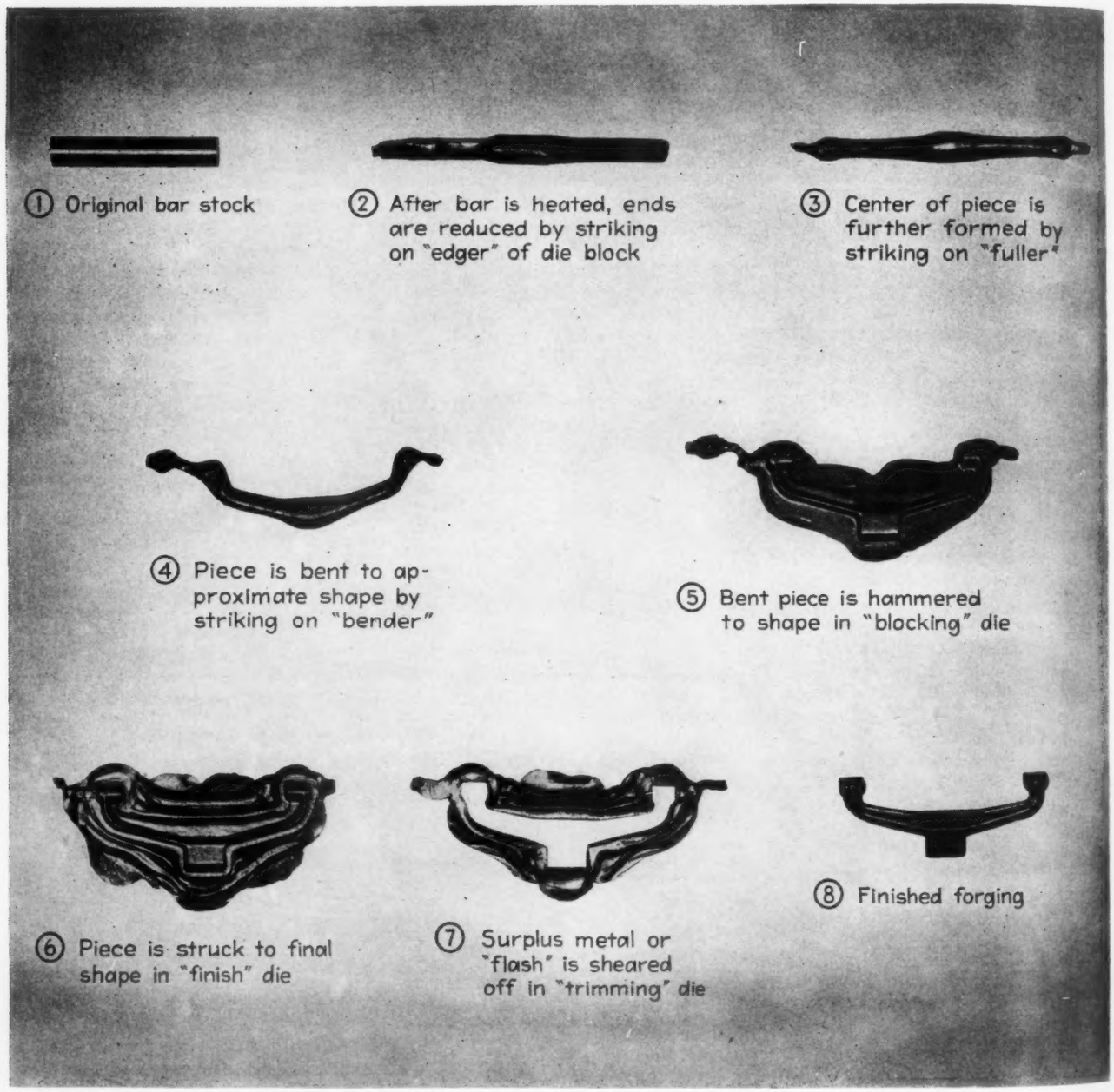
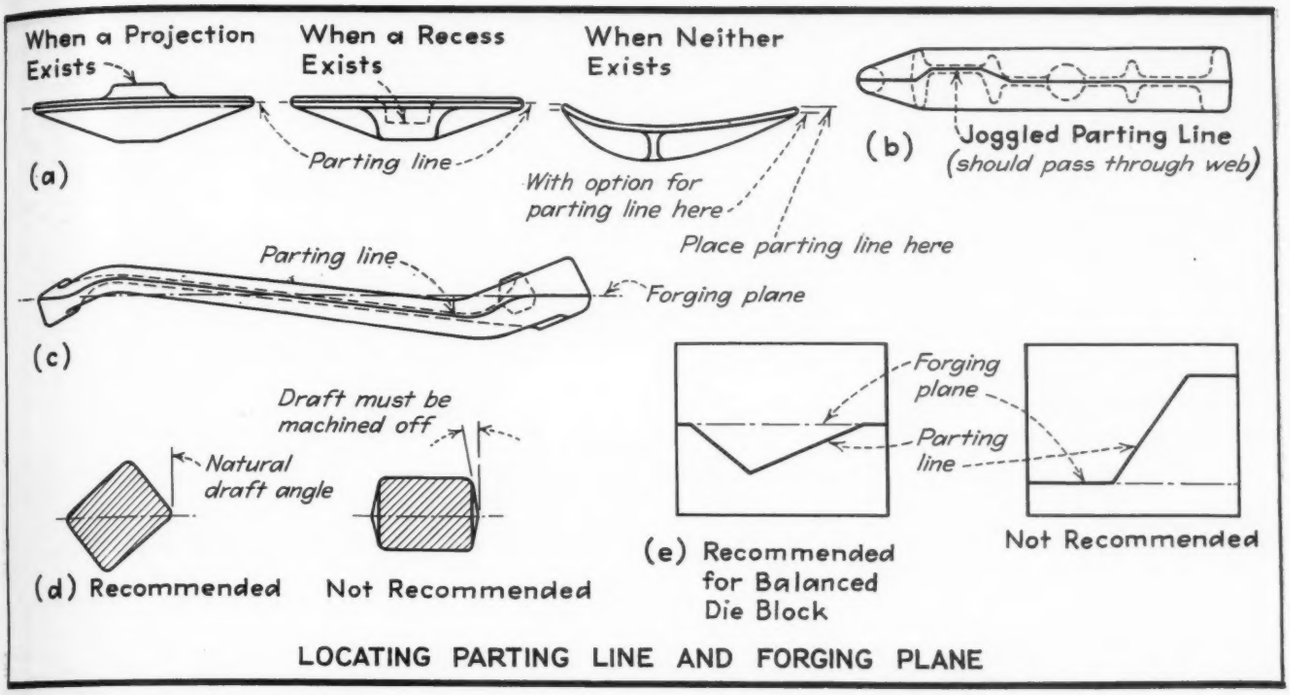
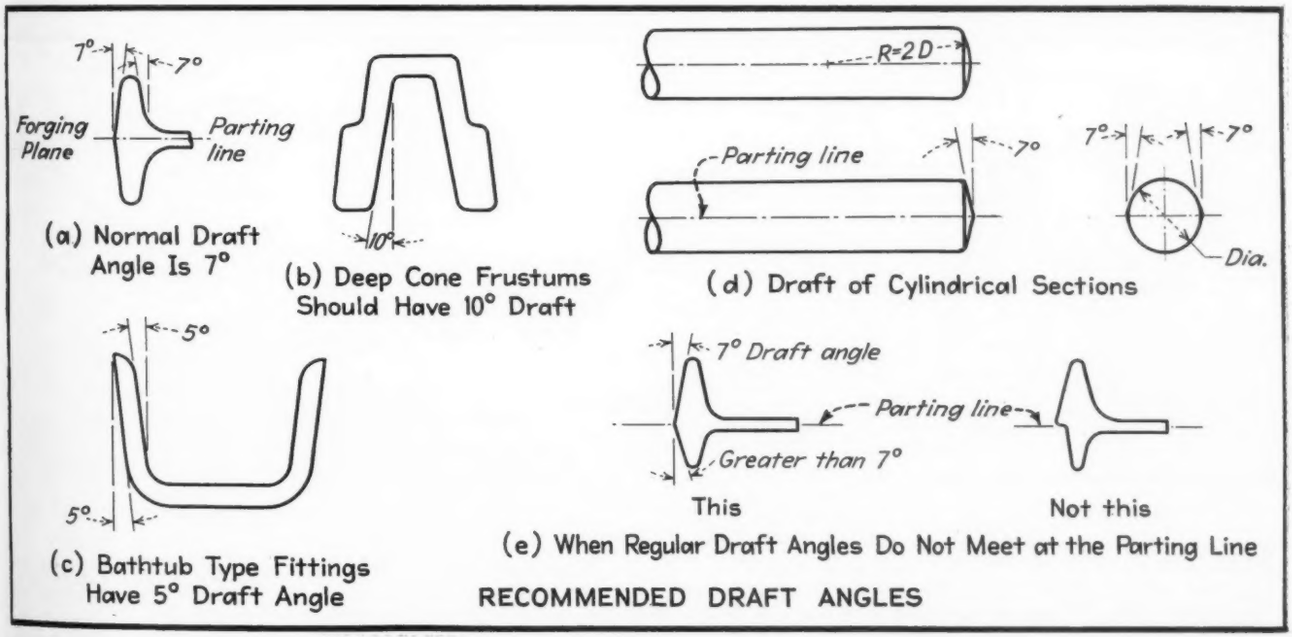

① Original bar stock
② After bar is heated, ends are reduced by striking on "edger" of die block
③ Center of piece is further formed by striking on "fuller"
④ Piece is bent to approximate shape by striking on "bender"
⑤ Bent piece is hammered to shape in "blocking" die
⑥ Piece is struck to final shape in "finish" die
⑦ Surplus metal or "flash" is sheared off in "trimming" die
⑧ Finished forging

Fig. 1—Some or all of these steps are followed in the production of a forging. Several die sets are required to carry out these steps with complicated forgings, but simple designs may call for only one combination die which contains all the necessary impressions



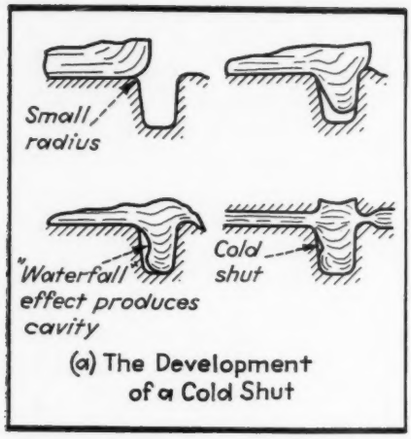
LOCATING PARTING LINE AND FORGING PLANE

Forging plane and parting line. The parting line should be located on the drawing of the forging blank according to the rules illustrated in sketch (*a*) above. When possible, the parting line should be so located that one die half contains all of the impressions to shape the part. Such drawings should give an option for single or two-die manufacture. Single dies may incorporate broken parting lines. Except for single dies, the parting line should run through the profile of the web, if one exists as shown in (*b*). The forging plane should be selected to (1) avoid unbalanced die load; (2) prevent interference between part and die in motion; (3) minimize subsequent machining by taking advantage of natural draft angles in either the plan view or on cross sections. These principles are shown in (*c*) and (*d*). Die lock, sketch (*e*), should be balanced to prevent side thrusts. The die sinker can, if necessary, remedy unblanced die lock by placing an opposing or counterlock in the die away from the forging surface.



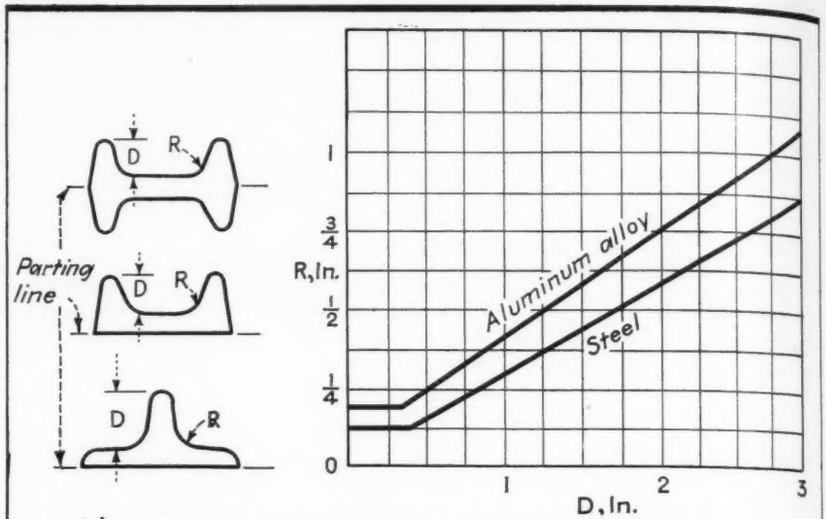
RECOMMENDED DRAFT ANGLES

Draft angles ranging from 7 to 10 deg. are necessary to prevent the forging from sticking to the dies. Draft always originates from the parting line, but the draft angle must always be measured from the direction of stroke of the forging press. Draft increases with die wear. Sketches (*a*) and (*b*) above show proper draft angles for various details. Bathtub type fittings (*c*) have 5 deg. draft angles, both inside and out, to prevent die breakage. For cylindrical sections, radial drafts result in the plan view when natural draft is used on circular sections. The end radius is drawn as shown in (*d*), but is not dimensioned. When regular draft angles do not match at the parting line, the draft in one die should be increased as shown in sketch (*e*) until both of the draft angles meet at the parting line.

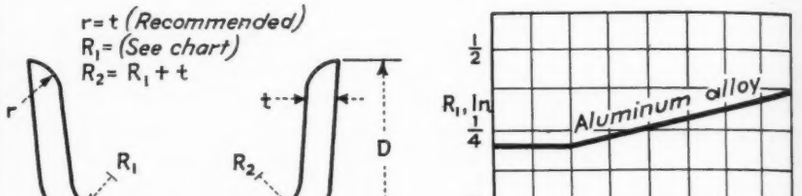


(a) The Development of a Cold Shut

Minimum fillet radii for maximum production of forgings are charted at right. In no cases should they be below 1/8 in. Too small fillets restrict the flow of metal into the deeper recesses of the die, resulting in a folding of the metal on itself, termed a "cold shut," shown in sketch (*a*) above. Values shown in (*b*) are for sections having width-depth ratios approximating 2 to 1, and for all T-sections. Fillets for bathtub type fittings are shown in (*c*) and for web-radius proportions of other section see next page.

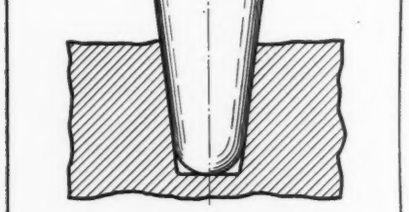


(b) Sections Having Width-Depth Ratio Approx. 2 : 1



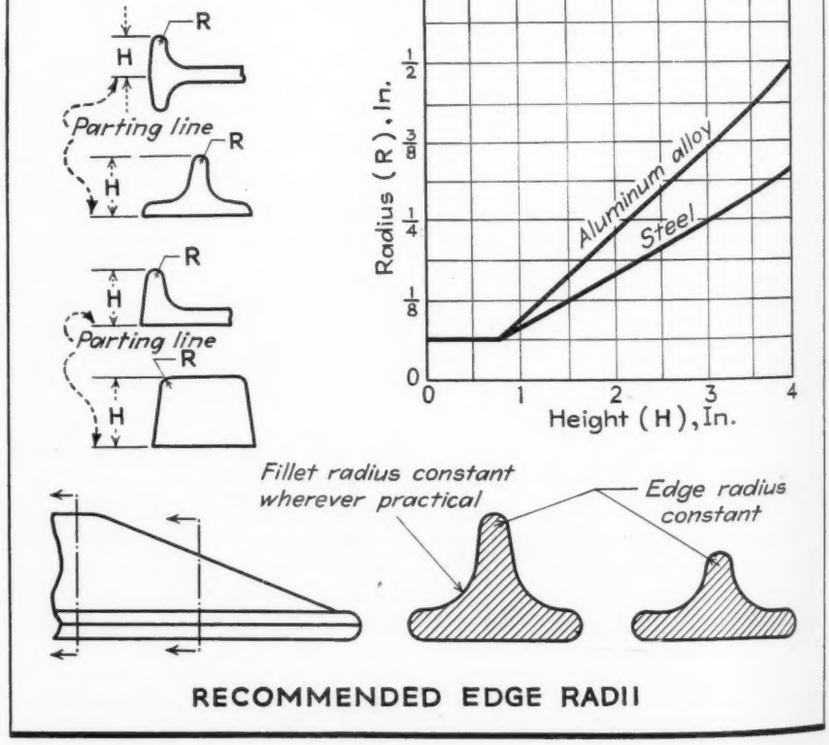
(c) Bathtub Type Fittings

RECOMMENDED FILLET RADII

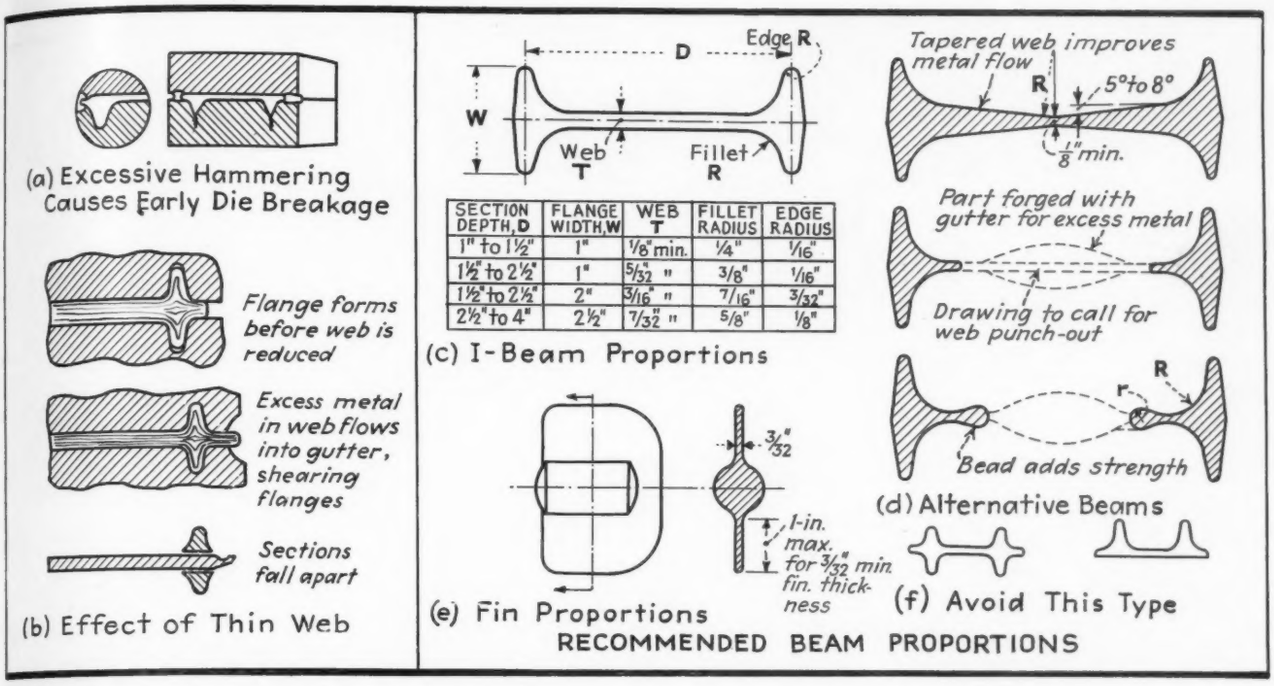


Effect of Small Edge Radii

Edge radii should exceed the minimum values recommended at right. Too small edge radii necessitate excessive hammering which, in turn, causes rapid die wear and early breakage. Relatively wide flanges should have full radii for better metal flow. To facilitate die sinking, corner and edge radii should remain constant along ribs and flanges, even though the section varies in height throughout its length.



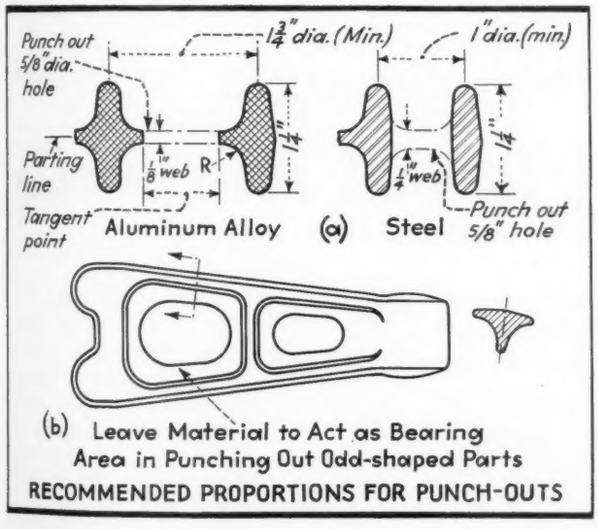
RECOMMENDED EDGE RADII

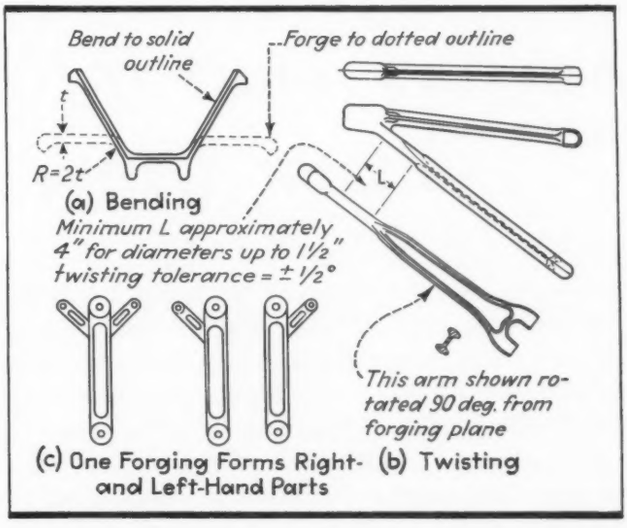


SECTION DEPTH, D	FLANGE WIDTH, W	WEB T	FILLET RADIUS	EDGE RADIUS
1" to 1½"	1"	⅛" min.	¼"	1/16"
1½" to 2½"	1"	5/32" "	3/8"	1/16"
1½" to 2½"	2"	3/16" "	7/16"	3/32"
2½" to 4"	2½"	7/32" "	5/8"	⅛"

RECOMMENDED BEAM PROPORTIONS

Web-radius proportions shown in sketch (*c*) at right are recommended for I-beam sections. Thin webs have relatively great area of contact against the cool die, thereby dissipating heat rapidly, and in their cooler condition become difficult to forge. As a result the part must be hammered more severely, thus causing rapid breakage of the die. On the other hand, the deeper cavities may fill or offer strong resistance to filling before the web is brought down to size. The flow of excess metal into the gutter will then shear the sections into separate parts. These conditions are shown in sketches (*a*) and (*b*). When it becomes impractical to adhere to web thickness indicated in (*c*), several alternate designs (*d*) may be used. For small parts having fin-like projections from a globular center, use minimum proportions shown in (*c*). These dimensions should be exceeded if possible for lower cost.




Bend to solid outline
Forge to dotted outline
t
R=2t
(a) Bending
Minimum L approximately 4" for diameters up to 1½" twisting tolerance = ± ½°
L
This arm shown rotated 90 deg. from forging plane
(c) One Forging Forms Right- and Left-Hand Parts
(b) Twisting

Punching and trimming. In order to minimize distortion of adjacent metal during punching-out operations, use the recommended proportions for aluminum alloy and steel shown in sketch (*a*) above. A small amount of material (approximately ½ in.) should be left around the inside of an irregularly shaped part to serve as a bearing surface for the punching operation. Trimming the flash from a forged part is a difficult operation to control. Trim lines may vary from $\frac{1}{16}$ in. undersize to $\frac{1}{16}$ in. oversize. Large parts may be as much as $\frac{3}{16}$ in. oversize. When the trim line must be held to close tolerances, the drawing should clearly dimension and specify, but such cases should be kept to a minimum.

Special designs, shown above, include bending, twisting, double parts, and left- and right-hand parts. Forgings can be bent in either the hot or cold condition. Bends should be located to provide for the necking down which occurs on the tension side of the bend, and the squeezing out which occurs under compression. Minimum radius of bends should equal twice the thickness of the part. Forgings may be twisted provided allowances are made as shown. Minimum length of twist should be approximately 4 in. for diameters up to 1½ in. Twisted tolerance is plus or minus ½ deg. At times forgings may be made symmetrical and rough sawed to form either left-hand or right-hand parts as shown.

These military airplanes prove the practicability of three materials in highly stressed structures

Factors That Influence Design When Using Different Materials

In the design of light-weight structures the relative importance of different properties will vary with the material used. The problem is one of coordinating different properties of the material used so that the material will serve most effectively. Some of the more important considerations such as the effects of differences of properties on stiffness, shear strength, modulus of elasticity are discussed here briefly. Among the important materials are aluminum alloys, stainless and other steels, and plywoods for highly stressed structures, and plastics and magnesium alloys for smaller parts and accessory equipment.

BECAUSE of the intensive efforts put forth in the design of highly stressed light-weight structures to replace aluminum with other metals, or with plywood or plastics, many new and ingenious types of light weight design are being developed. Much has been learned from tests and stress analyses made. Perhaps of greatest significance, the long-known fact that the weight of a structure is not a function of the strength-weight ratio of the material used, is now not only firmly established, but is also more generally recognized. Indeed, there is so little difference between the strength-weight ratio of different materials that this factor is obviously a subordinate one. Also, the fact that airplanes have long been made of aluminum with a strength-weight ratio of about 7, while alloy steels have a strength-weight ratio as high as 10, is clear evidence that this factor in itself has little significance.

A complete analysis of the relative merits of various materials for use in highly-stressed lightweight structures is impossible. Too many factors are involved. But it has been established that a lightweight structure can be designed to be made of any one of a number of different materials with little difference in final total weight be the material a steel, aluminum alloy or a plywood. Only the lack of neccssity for exhaustive stress analyses has prevented earlier discovery of this fact.

In addition to tensile strength and

density, the following properties of the materials under consideration play an important part in the design of structures: modulus of elasticity, fatigue strength, impact strength, shear strength, ratio of tensile strength to shear strength, corrosion resistance, workability of the material with reference to operations such as bending, machining, resistance welding and fusion welding, and other properties. All of these properties must be considered both individually and in relation to one another. Most of the errors made when designing with a new or unfamiliar material arise from the fact that its properties are not in the same proportion to each other as those of the long used familiar material. For example, shear strength of steel is about $\frac{1}{3}$ its tensile strength, which is usually sufficiently high to give satisfactory resultant shear stresses without investigation. But in wood the shear strength may be only 1/20 the tensile strength and therefore the designer must carefully investigate and check all possible shear stresses.

The problem of selecting the material for a lightweight design is not merely selecting between steel and aluminum, for example, but also among all the alloys of each and will be further complicated if composite materials such as metal reinforced plywoods and laminated bonded metal sheets are to be considered. However, composite materials have not yet proved suitable for highly stressed members and, therefore, will not be considered in this article. Laminated plywood, on the other hand, is now being used extensively and has been found highly suitable for many highly stressed structures. Therefore it is included among the materials which will be discussed in this article, the other materials being aluminum, stainless steel, low alloy steel, plain carbon steel and magnesium.

Pure Tension

On the basis of tensile strength only, the relative weights of tension members of equal strength would be in the same ratio as the weight-strength ratio of the respective materials. But there is practically no such thing as a structural member subjected to pure tension only. Although the principal stress in a member may be tension only, there are bound to be shear stresses at connections, compressive stresses caused by eccentricity of loading, and in any case there is always to be considered the resultant shear developed by a tensile load, which is maximum across the cross-section at 45 deg. to the axis of the member.

In practically every structural calculation the tensile strength of the material is a factor, but in no case is it the only materials property factor that enters into the calculation.

Shear Strength

A dangerous pitfall when designing a structure to be made of an unfamiliar material is the failure to take into consideration the ratio of tensile strength to shear strength. For aluminum this ratio is about 1.6, for steel it is about 3, but for wood, the tensile strength parallel to the grain may be as high as 12 times the corresponding shear strength. For plywood the shear strength may be $\frac{1}{8}$ of the tensile strength when the grain directions of the plies are at angles to one another.

In a bar subjected to an axial tensile or compressive load, the maximum unit shear stress is developed across the sections at 45 deg. with the axis of the member and the maximum unit stress developed is one-half the unit stress developed by the tensile or compressive load across the section at right angles to the axis of the member. Because the shear strength of aluminum is more than one-half its tensile strength, and for steel is about one-third, the shear stress in a tension member is usually not even considered. But when designing for plywood, the relatively low shear strength of the material will often make it necessary to design the member to resist shear, even though the principal stresses are tension or compression.

Similarly, in rectangular beams the maximum unit shearing stress at any section is 50 percent greater than the average across that section and in beams of circular cross-section it is 33 percent greater. Here, again, special care must be exercised when changing from metal to wood to make certain that although the tensile stresses are safe, the shear stresses will not be exceeded.

In designing the connections for plywood members, the joint must be carefully analyzed for shear stresses if a bolted or riveted connection is used. Shear stresses will be developed in the margins and in the sections between the bolts and lying in the plane determined by the axes of the adjacent bolts. These shear stresses may exceed the shear strength of the plywood, whereas when designing with metal such a condition is not encountered because of the high shear strength relative to the tensile strength.

Further with reference to bolted connections between plywood members, the high yielding of the material, that is, its low elastic modulus and high yielding under stress, results in a load distribution among the bolts or rivets entirely different from that in the case of metal members. This is further aggravated by the fact that the bearing load exerted by the bolt tends to split the wood and will split it if there is insufficient edge distance.

Elastic Modulus Factors

Modulus of elasticity not only determines stiffness but also is a factor that enters into the load-carrying capacity of columns and sheets subjected to compression. The load-carrying capacity of a given slender column varies with the modulus of elasticity of the material it is made.

When compression members consist of formed thin sheets, load-carrying capacity is usually determined by failure resulting from local buckling rather than by failure as a column. Here, again, the elastic modulus is a determining factor, but the yield strength of the material is involved also. Whether local buckling occurs in a wide flat section or in an unsupported edge, the resistance of the column or compression member to local buckling will vary with the elastic modulus of the material and the yield strength of the material. Limiting values of b/t, the ratio of allowable flat width or height of unsupported flange to the sheet thickness of alloy steels, aluminum alloys and magnesium alloys, are comparable and each material falls within a narrow range, from a minimum of 8 to 13.5 maximum.

Stiffness Factors

The need for stiffness in thin web sections and monocoque shells has made materials of lower density attractive to designers because small increases in thickness give large increases in stiffness of the web or shell. However, more exhaustive analysis of stresses in steel members has enabled steel construction of low weight also.

In most constructions EI, the product of modulus of elasticity times moment of inertia, is the measure of the stiffness of the structure. Therefore, when changing from one material to another, the cross-sectional dimensions of the members must be changed to give a new value of I inversely proportional to the values of E of the respective materials if equal stiffness is to be retained.

If in the redesign of a rectangular beam the depth cannot be changed, the change in I can be obtained only through the thickness. For equal stiffness the thickness will be inversely proportional to the elastic modulus of the material. Thus, in changing from steel to aluminum, the elastic modulus of which is approximately 2.8 times that

of steel, the thickness and hence the cross section of the beam would be increased 2.8 times. The aluminum beam would, therefore, be practically the same weight as the steel beam.

However if the cross-section of the beam were increased proportionately in all dimensions, because the moment of inertia is proportional to the fourth power of the dimensions of similar cross-sections, the dimensional change would be in inverse proportion to the fourth root of the ratio of the elastic moduli. In changing from steel to aluminum this factor is the fourth root of 2.8 or 1.29. In this instance the aluminum beam would weigh slightly less than one-half the weight of the steel beam.

In view of the many possible ways of changing the I of a section it is obvious that the weight of the resulting structure will depend largely on the ingenuity exercised by the designer. There are also factors such as local stiffness or buckling strength, joint effects and others to be considered.

In sheet constructions subjected to compressive stresses parallel to the surface, such as webs in compression, for a given construction the strength of the structure is roughly proportional to the cube of the skin thickness. This will vary considerably for different arrangements of stiffeners and therefore each construction must be analyzed in detail. For example, in monocoque shells with longitudinal stringers, the strength of the structure against bending moments will diverge from exact proportion to the cube of the sheet thickness because a considerable portion of the load is carried by the stiffeners.

The desirability of using plywoods in place of metal in shell type structures is based upon the ability to minimize interior reinforcements by virtue of the increased stiffness of the thicker plywood shell. Along this same line, a wing-span made of mahogany base Duramold (specific gravity 0.54) may have a skin 0.208 in. thick. For the same weight an aluminum skin would be 0.04 in. thick. The effective longitudinal modulus of elasticity of the Duramold skin, having 70 percent of veneers with grain in the direction of load is 1,000,000. The stiffness factor, EI, of such a panel is then 1,000,000 times $0.208^3/12$, which equals 744. This is 13.9 times as stiff as aluminum alloy skin of the same weight. An all birch plywood of 0.76 specific gravity could be 0.147 in. thick. Its stiffness factor, based upon E_L equal to 1,350,000, would be only 310, which is only 5.8 times that of aluminum.

Lack of stiffness in thin gages of steel require close stiffener spacing, rolling beads into flat sheets to increase local stiffness, or other provisions to prevent buckling. In a certain airplane wing design the leading edge is formed with a combination of 0.005 in. thick corrugated stainless steel sheet spot welded to a flat 0.005 in. skin using $\frac{3}{8}$ in. deep corrugations with a $\frac{5}{8}$ in. pitch. The net result is reported to compare favorably with aluminum alloy design.

Connections

There are three common methods of making connections—riveting and welding for metals, and gluing for plywoods and plastics. Spot welding has much to recommend it and is preferred when it is possible to use it. When the material selected makes riveting necessary there is some sacrifice in tensile strength because of rivet holes. Much could be said for each of these methods as they affect structural design, as well as for the lack of bearing strength of plywood which must be considered in making bolted connections with metal or in removable wood to wood connections where use of bolts is necessary.

These are but a few of the considerations which must be dealt with in designing light-weight structures in any material. There is not space to cover other important factors such as fatigue strength, which is of course important to the long life of a structure. Corrosion resistance is of great value in using stainless steel but means have been found to minimize corrosion or weathering of other materials. Comparisons could be made for machinability, workability, impact strength, hardness, yield points and other properties that affect design.

From this brief discussion of a few of the factors affecting the design of structures it appears that the material of the future for light-weight construction may well depend upon where the most effort and ingenuity are applied. Differences in various properties of available materials are shown here to be no hindrance in the development of successful designs in comparable service and the farther these considerations go in inter-relating the properties of each material the more evident the conclusion becomes. However, new materials of high strength-weight ratio will still be sought and experiments with composite materials continued.

Table I—Physical Properties of Structural Materials

Material	Tensile Strength lb. per sq. in.	Modulus of Elasticity x10−6	Shear Strength lb. per sq. in.	Hardness Brinell	Yield Point† lb. per sq. in.	Weight lb. per cu. in.	Compression Max. Crushing Strength	
							Parallel to Grain	Perpendicular to Grain
Aluminum Alloys	16,000	10	11,000	26	7,000	0.1		
	70,000		40,000	130	60,000			
Steel — Low Alloy	75,000	28		150	50,000	0.283		
	150,000	29		288	128,000			
Steel — 18–8	75,000			135	30,000	0.285		
	185,000	26		460	140,000			
Magnesium Alloys	33,000	6.5	18,000	43	12,000	0.065		
	46,000		22,000	82	38,000			
Wood — Birch	15,000	1.78*	1,300*		9,500	0.026	7,300	1,590
		2.19*						
Plywood — Birch	27,700	3.4				0.044	23,000	
	29,700					0.046		
Wood — Mahogany	10,800	1.27*	860*		7,900	0.020	5,700	1,400
	11,600	1.32*	980*		8,800	0.030	6,500	1,760
Wood — Spruce	9,400	1.30*	750*		6,200	0.019	5,000	840
		1.36*						

* Figures apply parallel to the grain. Perpendicular to the grain the modulus of elasticity for birch is 97,450; mahogany, 72,000 to 104,000; and for spruce 48,000. Modulus perpendicular to grain is usually taken as one-twentieth of modulus parallel to grain.

† Yield point in compression for metals usually taken as the same as in tension. For 18–8 stainless steel the range used in one engineering department is 35,000 to 170,000.

Question and Comment

Sheaves for Wire Rope

F. L. SPANGLER

For most installations with wire rope, gray cast iron sheaves should be avoided and a harder metal used. One of the results of using sheaves of too soft a material is that the wire rope leaves its imprint in the sheave groove. Such a condition wears the sheave excessively and tends to shorten the life of the rope. Also, when a new rope is installed it is most unlikely that the strands of the new rope will fall in the old "tracks," or match the old corrugations, thereby leading to further wear of the sheave and developing a severe filing action on the rope. Under such a condition the new rope starts its service life under a handicap.

Some hold to the theory that soft sheaves will save rope by taking the abrasion themselves instead of abrazing the rope. Experience does not bear this out. Hard sheaves generally maintain a smooth tread surface; soft sheaves do not but are inclined to roughen and act as a file against the crown wires of the rope.

The roughening of sheave treads is further heightened by the tendency of some ropes to "barb," which is nothing more than a projecting of jagged broken wire ends from the body of the rope. If the sheave is soft, these wire ends dig into it. This trouble may be avoided by using preformed rope since this rope does not tend to form jaggers but retains its smoothness of surface even though breaks in the crown wires may be present.

Safe Unit Bearing Pressures of Ropes on Sheaves of Various Materials

Material	Regular 6x19	Lay Ropes 6x37 8x19	Flattened Strand Ropes
Gray Cast Iron	500	600	800
Carbon Steel Casting	900	1075	1450
Manganese Steel	250	3000	....

For Lang Lay Ropes, the values given for regular lay ropes may be increased 15 percent.

It is a simple matter to determine how hard the material of the sheave tread must be to withstand the pressure of the rope. In the usual case, where the rope at all times contacts half the periphery of the sheave, the formula is:

$$P = \frac{2L}{D.d}$$

where P is the maximum unit bearing pressure in pounds per square inch of the rope against the groove tread, L the rope tension in pounds, D the diameter of the rope in inches, and d the tread diameter of the sheave in inches.

For 6x19 regular lay wire rope of filler wire construction, which is a common rope for industrial applications, the minimum recommended value of d/D is 26. Substituting this value in the above formula, we have

$$P = \frac{L}{13\ D^2}$$

If the rope is of plow steel grade, and a factor of safety of 6 is used, the value of L/D^2 becomes 13,300 for $\frac{1}{4}$-in. rope, 12,500 for $\frac{1}{2}$-in. rope, and 12,000 for 1-in. rope. Taking a value of 12,500 as being fairly typical, and substituting this in the equation, we have

$$P = 961 \text{ lb. per sq.in.}$$

From the table of safe unit bearing pressures, this figure is found to be far greater than maximum bearing pressures recommended for gray cast iron. It is somewhat near that for cast steel and much below the safe bearing pressure for managanese steel. Therefore, under the conditions given, (fairly representative of those found in industry), the cast-iron sheave is plainly too soft, the cast-steel sheave will generally stand up satisfactorily under the rope pressure, and the manganese-steel sheave will stand bearing pressures that are several times higher.

If gray cast-iron sheaves are to give satisfactory service, the value of P must be considerably reduced by either increasing the size of the sheave or reducing the load on the rope.

Many different types of rope-operated equipment are today being supplied with sheaves made of heat-tested cast alloy steel containing manganese, molybdenum or other alloying elements. A hardness of around 350 Brinell is not uncommon with these alloy-steel sheaves. These sheaves stand up satisfactorily under almost all kinds of service. Where alloy-steel sheaves must be replaced, sheaves of at least as hard and tough material should be used for replacement.

The argument has been advanced that steel against steel should be avoided, and since the rope is steel the sheave therefore should be some other kind of metal, such as cast iron or semi-steel. This argument is not supported either by theory or practice. There is no reason why the use of steel against steel is more harmful than cast iron against steel. As already pointed out, practice provides ample proof to the contrary.

Unless they are made of hard, tough metal, sheaves and drums on the hoist lines of magnet cranes are particularly apt to show the imprint of the rope since the lines are continually subject to the magnet load while in use. Certain other applications, such as the digging lines of power shovels, also subject the sheaves to very heavy rope pressure.

It is important to remember that one can't save rope by destroying sheaves. The use of harder metal to prolong sheave life actually results in increasing the life of the rope.

Oil Situation in Germany

To the Editor:

Your columns have contained considerable information from time to time concerning the German oil situation and the possibility that the German war machine may be stopped ultimately by lack of fuel. I think there are some interesting points which you may have overlooked that have a bearing on the subject.

There are two factors which make it much less likely that Hitler will be stopped by lack of engine fuel than is popularly believed. The first is the development in Germany of synthetic oil

and substitutes, which are vital in that country because of limited oil supplies but which, of course, are not considered in any discussion of engine fuels in the United States because of our great reserves. The second is the remarkable development of the diesel engine in that country.

On my last visit to Germany, I had the opportunity, because of my connection with The Cooper-Bessemer Corporation, to investigate the production of diesel engines and the manufacture of fuels. Thousands of diesel engines were being constructed in Germany even then —for installation in tanks, trucks, tractors, trains and airplanes. In Germany, the diesel aircraft engine, as you perhaps know, is a reality and thousands of Hitler's planes are thus powered. This application of the diesel engine principle to the German war machine has resulted in a tremendous saving of fuel—and has upset the calculations of many "experts."

As you know, the work done by a diesel engine per gallon of fuel, whether it is to propel an airplane, pull a train, or dig a ditch, is about one and one-half to two times as much as that done by an automobile engine. In addition, the fuel is much cheaper.

But the above facts are rather widely known. The development of synthetics and substitutes in the Axis countries is the factor which really upsets the calculations of those who believe that the answer to the entire problem is merely a matter of adding up the total productions of the various oil fields under Nazi domination and then dividing the result by a figure representing the fuel consumption of the German military organization per day.

By the beginning of 1939, a tax of 51 cents a gallon had been imposed in Italy on gasoline and a 36 cent tax in Germany. The reason? To encourage the development of synthetic and substitute fuels. There also were direct subsidies. At that time, about one quarter of all motor vehicle transportation in the Axis countries was accomplished with synthetic or substitute fuels.

Gasoline made from coal gases was widely used. Alcohol made from vegetables was blended with straight gasoline. There were experiments with ammonia and acetylene. Some 25,000 vehicles in Europe used compressed gases as fuel. The German motorist, who had to pay 60 cents for a gallon for gasoline, could use city gas at a price equivalent to 43 cents a gallon. Forty-one cents worth of methane also took him as far as a gallon of gasoline. Propane-butane fuel was more expensive—equivalent to 61 cents a gallon—but one tank full took the motorist some 225 miles.

Other substitutes for gasoline and oil are oil made by hydrogenation, pulverized coal suspended in oil and oil "cooked" from corn, wood, algae, seaweed, leaves and similar substances in combination with limestone.

It is logical to assume that the rapid growth of synthetics and substitutes in Germany has been accelerated by the war. Although facts are hard to obtain since the war began, on either the diesel engine development in Germany or the synthesis of fuel, it appears to me that enough is known for those who predict an early defeat for Hitler on the basis of fuel exhaustion to be more cautious.

—B. B. WILLIAMS
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S.A.E. Spring Committee Claims Our Steels Superior

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"Tensile strengths of American steels are about 10 percent lower than for Swedish steels, especially in the range of wire sizes under $\frac{3}{16}$ in. dia. The fatigue life of American steels, assuming no flaws, is 20 per cent less than that of Swedish steel."

Special exception is taken to the statement contained in the second portion of this opening and it is felt that this information is entirely contrary to the facts and it is the concensus of opinion of this committee that such figures should be carefully checked before they are published. We have no doubt that an investigation among reputable producers of wire of American steels will confirm our convictions that wire sizes under $\frac{3}{16}$ in. dia. are being produced of American stock to higher tensile strength and to a quality at least equal to that of any Swedish steel received in this country before the war. As to fatigue life, numerous tests on various sizes of wire made by various mills and by various spring manufacturers as well as motor manufacturers, have confirmed the fact that production of valve spring wire made from American steels is at least equal in all respects and in some cases better than the Swedish material previously used.

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Editor's Note—It would be impossible for the editors of PRODUCT ENGINEERING or, we believe, any other magazine like it, to check thoroughly all figures in all articles. Our contributors are men of authority in the field of their contributions and we naturally assume their data to be correct.

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News and Summaries

Bill Gives President War-Time Power to Confiscate Patents

DURING THE PAST SEVERAL DECADES, a number of bills aiming to abridge or nullify the protections enjoyed by inventors under the patent laws have come before Congress. In each instance they failed to pass. On the other hand, a number of basic changes in the patent laws, which were passed in recent years, have virtually eliminated some of the genuine abuses of the privileges granted by the patent system. Now, however, at a time when industry and engineering are concentrating their thoughts and energies on winning the war, some of our politicians have seen fit to make another attempt virtually to nullify patent protection. In fact, the two bills (S.2491 and S.2303) now under consideration would go even farther, giving to the President of the United States in time of war or national emergency and to the Patent Commissioner in times of peace, a dictatorial power over life and death of patents. Some of the terms and conditions proposed for incorporation in patent grants include:

1. Bill S.2491. If the Commissioner of Patents deems that the operation of the patent grant "has resulted or is likely to result in a violation of the antitrust laws or is otherwise detrimental to the public interest, then the Commissioner (of Patents) may order the patentee to make the invention or discovery available to the public under such reasonable terms and conditions (as determined by the Commissioner of Patents) as he may prescribe."

2. Any interested person may at any time present a complaint to the Commissioner of Patents alleging failure or refusal of the patentee to meet some of the terms set forth above. The patentee will then be required to defend himself against this complaint. If his defense is unsuccessful, the Commissioner of Patents can then prescribe the terms and conditions under which the invention or discovery will be made available to the public and the Commissioner of Patents will determine what the just and reasonable compensation to the patentee might be.

3. The bill also requires that every sale, assignment, or other conveyance of any patent that has been or will be issued and that all agreements of any kind between the licensee and owner of the patent shall be in writing and must be filed with the Federal Trade Commission.

Bill. S.2303. The President of the United States is granted, in war time the authority to license any person under any patent or patents to manufacture, use or sell upon such terms and for such period of time as the President may prescribe—the President to establish a reasonable royalty to be paid to the owner or owners of the patent, it being left entirely to the discretion of the President as to what a reasonable royalty might be.

As expressed by Colonel H. A. Toulmin of Dayton, Ohio, "The situation as to the patent laws is extremely serious."

The danger is all the greater in that the war conditions might divert the attention from this attack on our patent system. In the October number of PRODUCT ENGINEERING, the provisions incorporated in the proposed patent changes will be set forth in detail and analyzed, together with the opinions and arguments of congressmen, patent attorneys and industrialists. Herewith are two unsolicited letters received by PRODUCT ENGINEERING concerning the proposed patent law changes.

To the Editor:

Have you been following the hearings on the Senate bills now being considered by Senator Bone's committee?

You'll find them interesting — disturbingly so. Under the guise of war duress, a new concept of patents, both revolutionary and destructive, is being urged upon the country in a ruthless manner. Calm, dispassionate inquiry has given way to trial by newspaper headlines.

Designers and engineers look to your magazine for leadership. You are one of the molders of public opinion in that field. Your readers at the moment are up to their ears in the business of winning a war and are probably not fully aware of the implications of the pending legislation. They need to be stirred and aroused to action.

Frankly, we're vitally interested because we are a small concern that believes Research contributes toward a better way of living. And we also believe the fruits of our labors are entitled to protection. There must be many more like us in other branches of industry that need to be aroused and united. Won't you let me know how you think your readers can be awakened to the implications of these bills?

ROBERT J. GRAY
Dewey and Almy Chemical Company

Herewith is a copy of a letter sent by W. F. Rockwell, president, The Timken-Detroit Axle Company, to the Senate Committee on Patents:

Office of President
Senate Committee on Patents
Washington, D. C.
Attention: Senator Homer T. Bone

Gentlemen:

We understand that your Committee has been holding hearings on Bills S.2491 and S.2303 since early in April, and has been hearing testimony largely on alleged defects of the present patent system from witnesses produced by the Department of Justice.

Some of this testimony as reported in the press has been given by individuals, including high government officials, who seem to have little or no knowledge of the present law, and no practical experience at all with the development of new products, or the practical operation of patents in our business life. I would therefore like to have this letter included in the record of these hearings so that it will be available for mature consideration by congress when these bills come up for action.

I feel certain from my intimate personal experience with patents for the past twenty years that the compulsory licensing provisions of Bill S.2491, will do considerably more harm than good, particularly to small manufacturers and individuals who cannot compete with large manufacturers set up for mass production, unless assured of the full protection that the present law purports to give on new devices.

Under a compulsory licensing system, organizations lacking in the ability and

energy to develop new products can wait for others to go through the years of expensive experimental work, expense and risks incident to the development of a new product and its perfection to the point where it can be profitably sold, and then infringe and at the same time apply for a license! Without undertaking any risks or expense incident to development work, and with the market developed, a well equipped copier could and would under such circumstances drive smaller energetic organizations out of business on any worthwhile development. The result will, I feel sure, almost certainly be to discourage development through placing a premium on letting others take the heavy development risks in bringing out any new product.

The proposed restrictions of the nature of licenses granted will also in my opinion be harmful to development of new products as a whole. Many inventions developed for application in one field of endeavor are useful in totally different fields. A manufacturer in many cases cannot grant licenses that permit direct competition in his own field without disastrous consequences to his own business, yet he can freely grant licenses of considerable value in other fields. Typical cases are the development of an improvement for truck axles or brakes that may be very useful in pleasure cars, or improvements in household oil burners that are useful in industrial burners. In each case a right to manufacture in one field would involve no competition in the other.

Proper price controls and geographic limitations imposed through patent license also serve very useful protective purposes from the viewpoint of an energetic organization, and in encouraging the spreading of development. Labor policies, shipping costs and manufacturing costs vary widely in different localities, and an employer in an area like Detroit with fair labor policies could not afford to try to compete with a licensee at a fair royalty set up in business in an area like eastern or central Pennsylvania for East Coast business, without safeguarding license provisions permitted under the present law.

The provision that a manufacturer must be sued before a seller also would give large chain organizations buying from small manufacturers advantages unfair to patentees for obvious reasons. And it would permit a distant manufacturer to invade the well developed home markets of the manufacturer who built and developed the business, forcing the owner of the patent to the expense of maintaining remote suits to enforce his rights. Litigation costs at home are a severe burden now, and if the cost of remote suits is forced on small patent owners, many of them will not be able to stand litigation costs.

I can see no purpose in recording assignments, licenses, etc., with the Federal Trade Commission except to create more bureaucratic red tape and interference with legtimate small business and inventors. It frequently is necessary to give special terms to secure a first licensee in a field and there is no more reason to broadcast income taxes or other intimate business information. Large businesses can take care of themselves without such advantages over their smaller competitors. The Patent Office in any event should be the recorder of patent assignments and agreements. We have too much confusion now in our government affairs without mixing the Federal Trade Commission into patent records.

The Courts have ample powers under the present law and have done an excellent job of preventing abuses under patent agreements. And one thing the theorists who draft our laws overlook completely is that no business relying upon patents can possibly be successful no matter what the agreements are unless the public is given real value for its money and wants the product.

The Bill S.2303, I feel, is equally harmful and unnecessary. Ever since 1910 the Government has had the right to use all patented inventions, and the remedy of the owner has been to seek reasonable compensation in the Court of Claims if he cannot reach an agreement with the Government. This being the case, the sole purpose of any change in this present law can only be to deprive patent owners of a right to fair compensation. It seems significant that the President's power to grant licenses under this law is not limited to the War emergency, and the right to recover damages accorded under the present law is taken away. What useful purpose can there be in giving such powers to the President and why should the President be able to take patents, applications, inventions and licenses without compensation to the owners who must by the terms of the proposed law then sue in the Court of Claims with all defenses reserved to the Government? Is the sole purpose of this proposed change to give the President power to force an owner of a patented invention developed by him out of business by taking his patent and then suing him as an infringer, while he must sue in the Court of Claims for compensation only? The present law gives the Government the right to use all patented inventions. I can see no other purpose.

What we really need is not change in the foregoing respects, but fair and honest administration of existing laws with sympathetic consideration and fair compensation to the individuals and organization with energy and ingenuity enough to bring out new products and devices for which the public is willing to pay a reasonable price. No device can be made successful without public acceptance so long as we have any measure of free enterprise left.

Much has been said of taking away rights from owners of patents in recent years, and many charges have been made, without foundation, that they are impeding war production. No thought seems to have been given to dealing fairly with them probably because they are in a working minority, producing things which can be seen, but at sacrifices and costs that cannot possibly be appreciated by those who do not know how and in many cases never tried to produce anything useful. . . .

Move to Classify Rubber and Synthetic

TO CONSERVE RUBBER STOCK and ultimately to enable industry in general to make the widest possible use of rubber products, American engineers are devising standard classifications, specifications and tests for both natural and synthetic rubbers. Initally the new rubber classifications are to be recommended to the War Production Board for use in the war emergency conservation program. Later, this work by a joint committee of the Society of Automotive Engineers and American Society for Testing Materials will serve to bring about thousands of new industrial uses.

Primary objective of work done during the past several months has been to obtain the most effective and economical use of rubber stock. To this end, the number of rubber compounds has been reduced to less than one hundred from several hundred. Physical properties, characteristics and standard tests for each compound have been established to facilitate use for such industrial purposes as providing resiliency and absorbing noise and vibration.

War Is Engineer's Main Business Now

ON THAT STATEMENT will be based the program planned for the Society for the Promotion of Engineering Education, according to Henry T. Heald, president of Illinois Institute of Technology and newly-elected president of the society. Three main problems, in addition to its regular program of maintaining a

steady flow of engineers, face the society in this war, President Heald said.

These are the maintenance of instructional and research standards, full utilization of the schools' facilities for war research, and maintenance of defense training on a college level rather than at a trade-school level. Engineering schools are already having trouble maintaining their staffs against demands for engineers in the armed forces, Mr. Heald said. If this trend is carried too far the supply of graduating engineers must inevitably fall off either in numbers or in quality of training. In regard to use of facilities for war research, President Heald opined that the equipment and personnel of many technological schools is still unmarshalled for the war effort.

The "too many engineers" plaint need not be feared, stated Mr. Heald. When peace returns, he said he had no doubts that reconstruction work and technological advance that are bound to come would more than absorb the engineers trained under wartime acceleration programs.

Thin Film Helps Measure Metal Surface Roughness

DETAILS OF METAL SURFACES can be clearly magnified as much as 20,000 times under the electron microscope by reproducing the microscopic hills and valleys of the metallic crystals on a very thin plastic film, which is then stripped off and placed in the electron microscope for examination. Film thickness of 1/500,000 in., equal to about a tenth of the length of yellow-orange light wave, has been found to be best by General Electric scientists Vincent J. Schaefer and Dr. David Harker.

After the metal sample is polished and etched for a few seconds with acid, it is dipped into a dish containing a solution of Formvar plastic in dioxane, a commercial solvent. It is necessary to do this within a few minutes after the sample has been etched and dried. Otherwise an infinitesimally thin film of grease or other contaminating material may form.

Reynolds Metals Offers to Furnish Finished Blanks

TO ACHIEVE a number of vital economies, the Reynolds Metals Company proposes that the equipment necessary to perform the operations of routing, blanking and shearing to exact sizes be moved from various aircraft plants to central locations as close as possible to the aluminum plants.

Production of finished flat parts at the source of the sheet supply has the following advantages:

1. An average of 30 percent of all prime sheet shipped to airplane builders is ultimately returned as scrap:

(a) Reduce the weight of the original shipment by 30 percent and save vital freight capacity.

(b) Eliminate unnecessary handling, conserve plant space and release freight capacity on scrap returns.

2. Scrap resulting from operations of shape making remains at the source:

(a) Ready for instant re-melting, recasting and rerolling.

(b) Carefully segregated as to alloys.

(c) Kept clean and uncontaminated by interested experienced hands.

3. Avoid duplication of facilities:

(a) Parts for many aircraft builders are made on a single set of machines at the source on mass production tools.

(b) Small runs on semi-automatic machines at isolated plants are eliminated.

4. Identical shapes for a number of builders may be economically produced in a single place on a volume basis.

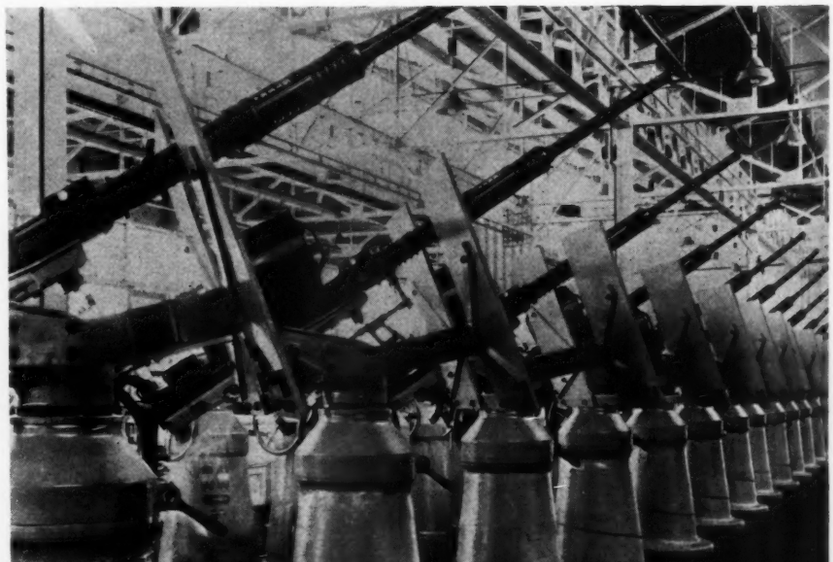
5. Skilled labor at the airplane plants is relieved of a job more advantageously handled at the source.

In view of the current shortage of raw material, a program of this sort would undoubtedly relieve this situation to a large extent. Surveys have shown that the scrap loss for prime sheet in various aircraft companies averages 30 percent or approximately 8,000,000 lb. a month. This actually means that there is approximately 16,000,000 lb. of idle aluminum. Half is potential scrap on its way to aircraft companies as prime sheet—the other half is actual scrap being accummulated and returned to the source for re-processing.

1,000 lb. Aluminum Saved In One War Plane

IT IS NOT GENERALLY RECOGNIZED the extent to which plastics and plywood are being substituted for aluminum in military airplanes. According to the Aircraft War Production Council, as reported by North American Aviation, Inc., in its house organ, the "Skywriter", as much as 1,000 lb. of aluminum are being saved in one type of war plane alone by the substitution of plastics and plywood. Plywood is replacing aluminum for such parts as troop benches, window frames, compartment linings and partitions, tail cones, fuselage noses, wing fillets, cabin doors, wing flaps, control surface tabs, nose wheel doors, antenna masts, air ducts, radio shelves, and life raft shelves.

In addition to plastics and plywood,



Part of a day's production is this line of 20 mm. Oerlikon guns ready to be shipped from the Naval Ordnance Plant operated by Hudson Motor Car Company. These anti-aircraft guns recently saved a convoy whose cargoes were worth more than the cost of the gun program, a Navy officer said.

low carbon steel is also being used extensively in place of aluminum. Perhaps the most striking example is the application of low carbon, low alloy steel in the construction of the North American AT-6A trainers. By ingenious design, the finishing structure in some respects surpasses the corresponding aluminum structure in strength and safety factors.

Industries Committee Boosts Scrap Program

To REACH every manufacturing and business firm in the nation and impress upon them the absolute necessity of getting their scrap on the way to the production line, and to get business men cooperating with local salvage committees of W.P.B. the American Industries Salvage Committee has recently been formed, it was announced by Robert W. Wolcott, chairman of the group and president of Lukens Steel Company. Supplementing contacts already established by the Industrial Salvage Division of W.P.B. the new committee will make a direct approach to individual industrial concerns. Leaders in 50 industries are being asked to serve as chairmen for their respective trades in a broad effort to see that every company appoints a salvage manager with authority not only to clean out production scrap, but also to junk obsolescent equipment and similar material.

Extend Felt Standards

ACCOUNTING FOR nearly 250 items in seven series, all of which are designated by wool content, width, thickness, color and tolerances, standards for wool felt have been extended to include the industry's principal production and competitive numbers, the Felt Association announces. Now included are sheet felts in hard, medium and soft grades to the very soft and pliant cushioning materials. Included also is kapok felt for sound-proofing and thermal treatment of airplane cabins. The new list incorporates S.A.E. standards for wool felt and the complementary A.S.T.M. methods of test.

Two New Ansco Products Available After the War

COLOR PHOTOGRAPHIC FILM that can be developed by the amateur by ordinary dark-room methods, and of an unusually high quality in the faithful reproduction of color shades and tones, was recently exhibited as one of the latest products of the Ansco Company research laboratories. The other development demonstrated is a new type of sound track made on sensitized cellophane instead of the conventional silver film with surface emulsion.

The new Ansco color film gives amazing results with reference to both true-color and remarkable detail. One of the examples exhibited was a photograph of a house and garden wherein seven distinct shades of green could be clearly seen. But of perhaps equal significance is the fact that it is not necessary to send the exposed film to the factory to be developed. An amateur can readily develop the film.

The new sound film developed by Ansco research uses a thin strip of cellophane impregnated with diazo compounds. This sensitized film is printed by contact with an original photographic recording and then developed in ammonia fumes. The whole processing, printing and developing is done in one continuous operation at a speed of 80 ft. per min., and in daylight, not in a dark room. The prints are then ready, without need for washing, fixing or drying.

Ozaphane, as this new film is called, costs only about one-tenth of what a silver film costs and has many points of superiority. It is small and compact. A roll the same size as a 1,000 ft. roll of silver film will play 60 min. as compared to 18 min. for a silver film.

In normal times a company announcing new developments immediately places them on the market. But in this case, Ansco announced that so long as the war continues, its complete output will be absorbed by the Army and Navy and it will not produce its new color film and Ozaphane for the market.

Cast iron bearing, weighing 4½ tons, has been polished to mirror-like smoothness to support 1,000-ton weight of waterwheel and electric generator rotor. Made by Westinghouse Electric & Manufacturing Company, it is here being checked before being shipped to Grand Coulee Dam for assembly in one of the 18 giant 108,000-kw. waterwheel generators Grand Coulee will have.

Meetings

National Metal Exposition—"War Production Edition," Public Auditorium, Cleveland, Ohio, Oct. 12–16. W. H. Eisenman, Managing Director, 7016 Euclid Ave., Cleveland, Ohio.

American Society for Metals—National Metal Congress and annual meeting. Cleveland, Ohio, Oct. 12–16. W. H. Eisenman, Managing Director, 7016 Euclid Ave., Cleveland, Ohio.

15th National Exposition of Power and Mechanical Engineering—Grand Central Palace, New York, N. Y., Nov. 30–Dec. 5. Charles F. Roth, manager, Grand Central Palace, New York, N. Y.

Do You Know That—

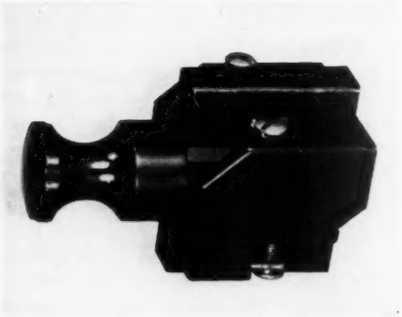
CANS WITH FIBRE BODIES, reasonable facsimiles of tin cans previously used, can now be turned out on the same machines used for the metal cans. (14)

REVERSIBLE PITCH PROPELLER recently developed sends boats full speed astern or forward without reversing the engines or shifting gears. (15)

New Materials and Parts

Push-Pull Button Station For Motor Controls

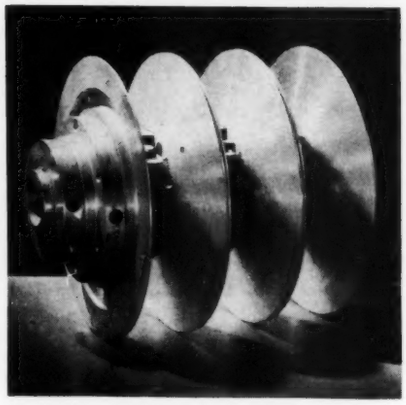
New safety push-pull button heavy-duty interchangeable units feature greatly increased safety and economy, plus the convenience of positive and simplified means of control. By incorporating both the push and pull action in one button, two operations are thereby performed which cuts in half the number of buttons formerly required in a control circuit. The normal position, or point of rest, is in the center. Definite action is required to move the button momentarily in either direction from the center. The button is pushed to stop the motor, but it must be wilfully pulled to start. Also, the use of one button to perform start and stop operations eliminates the necessity for the operators to



stop and look to see which of two buttons should be pressed. The line includes the following types: Push-pull, momentary, 3 position, (start-stop). Push-pull, momentary and maintained, 3 position, (1-off-2). Push-pull, maintained, 2 position, (on-off). Pull, momentary, (start). Push, momentary, (stop). The Arrow-Hart & Hegeman Electric Co., 103 Hawthorne St., Hartford, Conn.

Wide Range Variable Sheave

Speed variations from 66 to 116 percent are possible with this new wide-range sheave, designed to be used with a companion sheave grooved for the new, wide Texrope V-belts. Manufactured in sizes to fit the shafts of all standard NEMA motors from fractional to 30 hp., wide-range Vari-Pitch sheaves provide a flexibility that is proving especially adaptable in textile mill and machine tool applications, where wider ranges of speed variations are increasingly in demand. Companion sheaves are made in sizes to meet the requirements of the wide-range applications. Allis-Chalmers Mfg. Co., Milwaukee, Wis.



Electric Starters

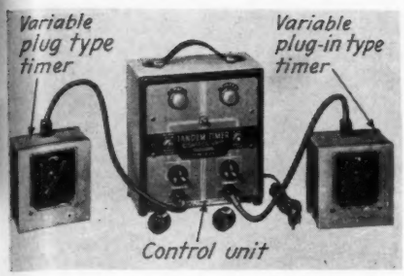
Designed for aircraft engines up to 400 hp., tanks, landing barges, cargo freight liners and similar applications, this new line of direct cranking electric starters is claimed to have the highest power for its size of any equipment of this type. Compact design includes an improved safety clutch. Positive action is transmitted to the crankshaft through multiple gear reductions and driving jaw. Either 4-in. or 5-in. standard mounting pad is supplied. Right hand or left hand rotation is available. All starters are equipped with starting solenoids and inclosed type safety starter buttons. Model 1300, which will crank some 400 hp. aircraft engines, weighs less than 20 lb., is 9¼ in. long over all, 5¾ in. wide, and 7 in. deep. Champion Aviation Products Co., Los Angeles, Calif.

Foot Treadle Switch

New snap-action foot switch, mounted in a sturdy cast-iron casing, is fully inclosed and hooded for protection against dirt and chips. Snap-action is rapid. There are four switch blades with wiping action. Arcing is kept at a minimum. The switch has been tested to over 250,000 offs and ons, showing no deterioration of parts or arcing effect. Heavy spring under cover avoids load on spring mechanism of the switch proper. Also adaptable to knee action. Rated at 20 amp. on 250 volts a.c., its size is 7 x 4 x 3¼ in., and its weight is 5¼ lb. Available in two models: double action for press to start and press to stop, and momentary contact for hold down for closed circuit. Simonds Machine Co., Inc., Southbridge, Mass.

Versatile Timing Device

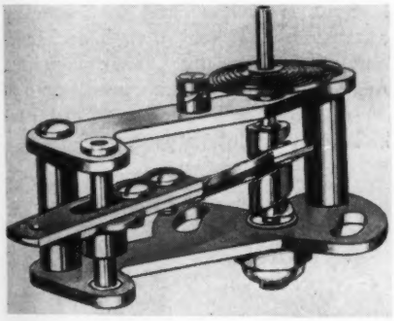
Tandem Timer permits practically any timing sequence that may be desired in laboratories, production lines, and for life testing of electrical apparatus. Automatic reset features make continuous, as well as single cycle of operation possible. Control cabinet measures 8½ x 8½ x 5 in., and contains the on-off toggle switch, repeat and single-cycle toggle switch, single-cycle start pushbutton switch, pilot lamps, receptacles, and sockets into which are plugged the two timing elements which control the single-pole, double throw,



load relays. Timing elements are synchronous motor-driven, automatic resetting timers, of sturdy design and construction, contained in a formed steel box measuring 5 x 5 x 3 in. Graduated dial and pointer knob allows quick and accurate selection of timing period. Six standard models available, offering setting from ¼ sec. to 2 hr. 45 min. Industrial Timer Corp., 113 Edison Place, Newark, N. J.

Gage Mechanism

New and improved type of gearing in the form of cam and roller movement has been developed for use in pressure-indicating gages. The movement employs a sector-shaped driving cam and a driven helical roller. One end of the pivoted cam is linked to the tip of the



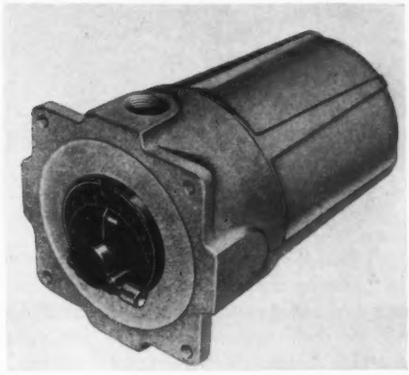
Bourdon tube, while the other end is aligned with and fits freely into the thread of the roller. A hair-spring limits the point of contact between cam and roller to only one side of each element, and prevents backlash. As the edge of the cam is in constant contact with the wall of the helical thread, there is no lag nor lost motion between these parts. Overstretch or collapse of the Bourdon tube cannot jam the internal mechanism. Driving cam is faced with plastic which shows no wear after millions of cycles of operation. Ball-shaped roller pivot rides on a bearing of dissimilar metal, minimizing friction of rotation. Back adjustment screw is available on all large gages, and effects positive recalibration without the necessity of opening the case. Certified Gauge and Instrument Corp., Long Island City, N. Y.

Water Tight Sockets

New water tight socket which takes a standard medium base Edison lamp is made of cold molded composition, outside diameter 2¾ in., total depth without contacts 1½ in. The Woodwin No. 860 has four holes around the top circumferences through which the holding screws are placed. These holes are 2¼ in. center-to-center across the circumference of the socket. Meets specifications of the Maritime Commission. C. D. Wood Electric Co., Inc., 826 Broadway, New York, N. Y.

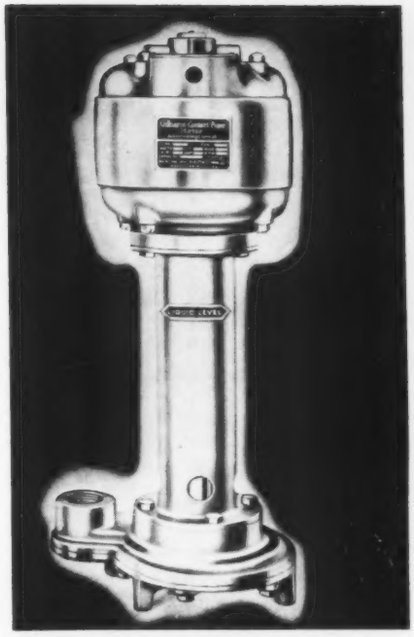
Explosion Proof Timers

Type TD1C and TD1 explosion proof timers are suitable for operations in atmosphere containing gasoline, naphtha, petroleum, benzol, acetone, lacquer solvent, natural gas, and other explosive atmospheres. The illustration shows a Type TD1C explosion proof time delay relay which is laid out for panel board mounting with the setting knob and dial projecting. Within this housing it is feasible to mount either a TD1C or a TD1 with a small relay. The latter construction would be used where it is desired to control the timer from remotely located momentary start button. The R. W. Cramer Co., Inc., Centerbrook, Conn.



Coolant Pumps

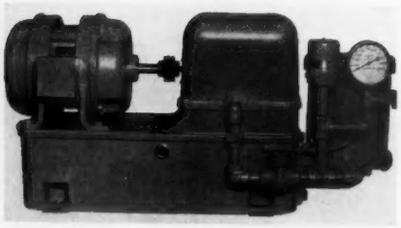
Two new centrifugal coolant pumps, Model CE immersion type, and Model CF flange mounted type, are compact integral units consisting of motor, pump, and built-in terminal box. Motor, ¼ hp., is totally inclosed and designed for continuous operation without overheating. Ball bearings are permanently grease packed and there are no bearings below the liquid level to be affected by abrasives in the coolant. In the immersion type pump, perfect alignment of motor and pedestal is assured by rabbeting, and a heavy 1-in. dia. shaft elimi-



nates vibration. Impeller is bronze, open-type, statically and dynamically balanced, secured to the lower end of motor shaft by key and locking nuts. Pumps are self-priming and may run dry without any damage. They will handle filings and chips as large as 0.035 in. without damage. Bulletin is listed on "New Manufacturers' Publications" page. Gilbert & Barker Mfg. Co., West Springfield, Mass.

Hydraulic Power Unit

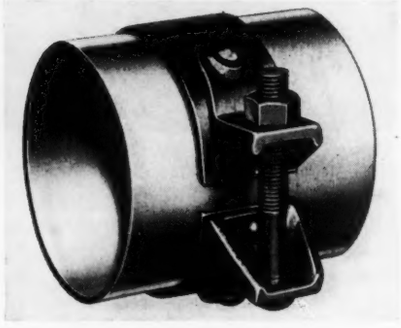
Model 5036 hydraulic power unit, designed specially for hydraulic chucking installations on machine tools, but adaptable to other similar applications, is capable of operating additional cylinders and sustaining the pressure during the different executions of the work cycle. Pressure is maintained without the electric motor running constantly by a spring-loaded accumulator. Built-in pressure switch of a non-diaphragm



type automatically shuts off the electric motor when accumulator has been charged to 550 lb. per sq.in. When accumulator has discharged sufficient oil to reduce hydraulic pressure to 450 lb. per sq. in., the pressure switch will again start the motor. Pump delivery is 8 gal. per min. Pressure range is from 550 maximum to 450 lb. per sq. in. minimum. Oil capacity of tank is approximately 15 gal. Capacity of accumulator is approximately 50 cu. in., at 550 lb. per sq. in. pressure. Electric motor requirements are 3 hp., 1,200 r.p.m., NEMA frame No. 254. Logansport Machine, Inc., Logansport, Ind.

Pipe Repair Band

A repair device for small pin holes, leaks, and splits in straight runs of pipe, Style 77A Band Clamp conserves pipe materials, is simple in construction, easy to apply, prevents further damage and loss of line contents where small defects in the line occur. The clamp is a heavy



one-piece steel band of circular split construction, with a riveted bolt lug at each end. A track-head bolt pulls the ends securely. Dresser Mfg. Co., Bradford, Pa.

Loose Pulley Lubricator

Designed to deliver a positive, constant and regulated amount of filtered oil through the shaft or bearing of loose pulleys, idler pulleys, clutches, eccentrics, and similar rotating machine parts, this lubricator consists of a glass oil reservoir mounted on a hollow metal stem. Except for two small ports at the top, the stem is sealed from oil in the reservoir. A felt wick inside the stem extends through the pulley hub and rests directly on the shaft. A compression spring is wrapped around the wick to hold it firmly in position against the shaft. As the lubricator rotates with the pulley, the centrifugal force throws oil against the top of the reservoir and into the two ports in the stem. Through them oil is admitted to the wick, which filters out all dirt and sediment and conducts oil to the face of the shaft. The amount of oil delivered is regulated by a small plug which controls area of oil ports. Five standard sizes are available in capacities from ¼ to 2½ oz., for standard tappings from ⅛ to ¼ in. Oil-Rite Corp., 3466 S. 13th St., Milwaukee, Wis.

Air Furnace Iron

Called "Afiran", this air furnace iron is made by a special melting technique which produces a uniform distribution of graphite flakes through a pearlitic matrix. Because of the close grained uniform structure, it has high wear resistance, withstands high pressures and is readily machinable. Afiran is manufactured in three grades, with tensile strengths of 30,000, 40,000 and 50,000 lb. per sq.in. It is not recommended where sections are less than ¼ in. thick, but has proved itself to be an excellent general purpose material. Terre Haute Malleable & Mfg. Corp., Terre Haute, Ind.

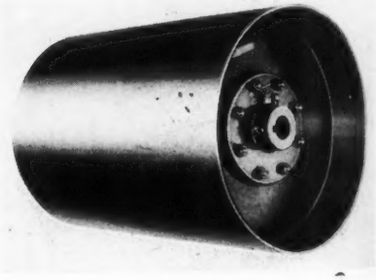
Blueprint Dryer

Weaco blueprint dryer permits drying of blueprints on the spot, and is claimed to dry a blueprint in approximately 5 min. It is made especially to

accommodate sheets of 30-in. blueprint paper in lengths up to 32 in. Chromium-plated drum measures 34 x 18 in. in diameter, and has a drying surface of 32 by 52 in. Heating unit for drying is 700 watts on 115 volts, either a.c. or d.c. operation. Heating element is guaranteed for five years. Drying belt is made of tough, pre-shrunk material. Warren Electric Appliance Co., Warren, Pa.

Conveyor Pulleys

Made with tight ends, the new Type N pulley for belt conveyors is easily kept clean. No spilled materials, dust or water can accumulate inside the pulley. Known as American Solid Conveyor Pulley, it is made of rolled steel, is light in weight, and is practically unbreakable. Removable, interchangeable hubs assure quick, easy mounting. Available in pulley diameters from 6 to 36 in. American Pulley Co., 4200 Wissahickon Ave., Philadelphia, Pa.



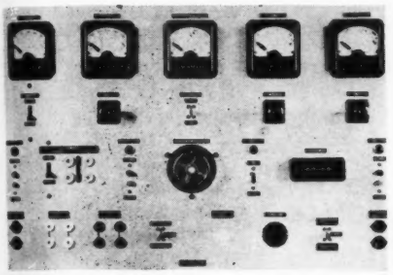
Boots Curved Channel For Aircraft

Consisting of the sheet metal wing style nut in combination with a curved channel strip, this curved channel has the important feature that permits nuts

to be replaced quickly and easily by snapping one out of the channel and snapping another one in its place. Curved channel is companion to regular straight channel. Available in standard semi-circles with radii ranging from 2⅜ to 11¾ in. Ordinarily furnished with nuts in standard regular spacing, but can be supplied on special order with irregularly spaced nuts. Boots Aircraft Nut Corp., New Canaan, Conn.

Electrical Testing Panels

Standard Panels are designed to give required flexibility of electrical connections necessary in research and development laboratories. Built for heavy-duty



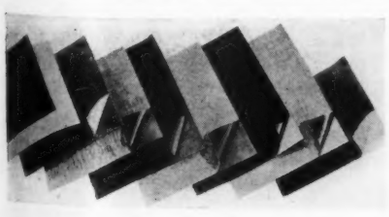
service, each Standard Panel is designed to meet individual requirements. Can be delivered promptly with high priority ratings. The Standard Electric Time Co., Springfield, Mass.

Slot Insulation

Non-bulking slot insulation, called "Irv-o-slot," is for use in confined or limited space. Insulation is available in sheet and tape form from which may be cut slot strips. Following types have been developed:

Type	Dielectric Strength, volts per mil
Resin-coated fish paper	600–800
Resin-coated spauldo	600–800
Varnished silk duplexed to fish paper	1,050–1,250
Thin varnished cambric duplexed to fish paper	800–1,000
Cambric duplexed to spauldo	800–1,000
Varnished fiberglas duplexed to fish paper	800–1,000
Fiberglas duplexed to spauldo	800–1,000

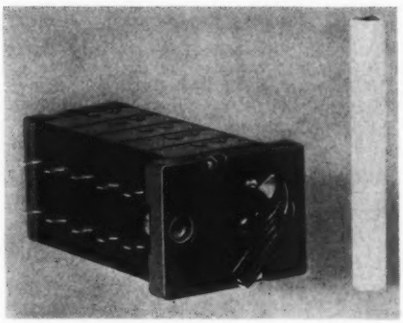
These materials, plus straight-cut and



bias-cut varnished cambric in heavier combinations are said to provide for all slot requirements. Irvington Varnish & Insulator Co., Irvington, N. J.

Multicircuit Switch For Aircraft Service

Capable of opening, closing or transferring as many as 20 circuits simultaneously by means of a two-position operating knob, this new multicircuit switch uses G.E. switchettes stacked in pairs as its contact mechanism. The switchette is snap action, double-break in construction, giving it a high current rating. The multicircuit switch is available with from 8 to 20 switchettes, and in either single-circuit or two-circuit form. A shaft toggle switch insures positive switch position. Meets specifications set up by U. S. Army Air Forces. Weight varies from 5⅓ to 10⅔ oz. depending on size selected. General Electric Co., Schenectady, N. Y.

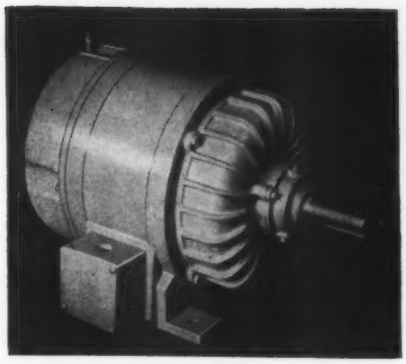


General Purpose Plastic

With slightly higher impact strength and greater water resistance than former top-grade general-purpose phenolic compounds, Durez 11540 is now adaptable to many new uses through a minor revision in its formulation. It is said to deliver excellent surface finish. Parts now being molded of this material include some which must withstand hard usage, such as field communication equipment, instrument cases, housings. It has met military approval for several war production parts. Durez Plastics & Chemicals, Inc., North Tonawanda, N. Y.

Totally Inclosed Motor

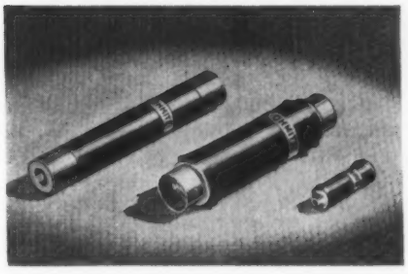
Totally inclosed, fan cooled, Type EA, Torq Motor is cooled by a large blast of cooling air directly over the stator laminations and end bells between the inner steel frame and the outer shell. Seal between end bells and stator frame is a machined rabbet. The motor is completely ball bearing



equipped, and bearings are inclosed and sealed in grease. Stator frame is welded. Rotors also are all-welded, and are carefully machined to insure proper air gap clearance. Shaft is ground, and motor is carefully checked for dynamic balance. Available in frame sizes from 203 to 326. Frame sizes 203 and 204 are totally inclosed but are not fan-cooled. Bulletin is listed on "New Manufacturers' Publications" page. Torq Electric Mfg. Co., 6607 Carnegie Ave., Cleveland, Ohio.

Ferrule Resistor

Designed to provide easy interchangeability without use of tools, Ohmite ferrule resistors are protected by vitreous enamel coating. Resistor wire is wound on a ceramic core, the wire terminated on cup, sleeve or cartridge-type metal ferrules. Special cores which will withstand thermal shock tests and protective coatings which defy salt water immersion are available. Ohmite Manufacturing Co., Chicago, Ill.



Saves Cleaning Time

New wrapping material, made of cellophane and laminated cotton scrim, can save hours spent in removing coats of protective grease from metal parts. Cellophane strengthens the fabric and adds to its acid and oil resisting qualities. Coverings may be closed by twisting ends or hot-sealing. Parts wrapped in "No-Ox-Idized" material may be cleaned at factory and shipped without further protection except light coat of oil or lump of silica gel inside wrapping. Dearborn Chemical Co., Chicago, Ill.

Books and Bulletins

Mechanics of Aircraft Structures

JOHN E. YOUNGER—*Second Edition. 396 pages, 6x9 in. Blue clothboard covers. Published by McGraw-Hill Book Co., Inc., 330 West 42nd St., New York, N. Y. Price* $4.

First edition of this book was published under the title "Structural Design of Metal Airplanes," of which about 40 percent of this second edition is a revision. Because of the great progress in development and expansion in types of airplane construction, the author has found it necessary in this present volume to limit the text strictly to the mechanics of the structure.

Following a description of airplane design requirements and a compendium of the properties of materials of fabrication, the author proceeds step by step with the analysis and design of typical elements and types of structures used in aircraft construction. The last three chapters deal with pressure-cabin structural design, wing flutter and other structural vibrations, and riveting in aircraft construction.

The book contains numerous graphs of the relations existing between the variable factors in design. Much tabular matter is also included that is valuable as reference data.

An Introduction to Control Engineering

ED S. SMITH—8¼ x 11 *in., 142 pages. Paper covers. Published by Ed S. Smith, c/o C. J. Tagliabue Mfg. Co., Park and Nostrand Aves., Brooklyn, N. Y. Price* $2.

The material included in this book is intended for the use of anyone working in the art of control and its applications in the process industries who wishes an introduction to the subject and its literature. It is assumed that the reader has studied the physics and mathematics which underlie the principles of operation of industrial instruments of the variable measuring and controlling class.

The first section of the book is mainly devoted to terminology and a descriptive treatment of control and its application, this is followed by sections covering quantitative analysis of control, various aspects of control, physics and lower mathematics used in control, and higher mathematics used in control. A list of reference books and papers is also included. A separately bound volume of figures supplements the book.

Engineering Index 57th Edition

Annual volume for 1941. *Compiled and published by Engineering Index, Inc., 29 West 39th Street, New York, N. Y. Price* $50.

This volume contains 26,000 annotations of important articles published in current technical periodical literature during the year 1941. Each annotation is appropriately cross-referenced for subject matter and topic; there are 40,000 cross-references to these annotations. Included in the volume is an index of authors and contributors. Also included is a list of the publications reviewed.

Industrial Statistics

H. A. FREEMAN—178 *pages, 6 x 9 in. Black clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y. Price* $2.50.

This volume deals with several of the statistical features of the problem of establishing a systematic program through which the quality of industrial output can be studied and controlled. Examples are given of the uses of elementary statistical methods in the design and analysis of experiments carried out in industrial plants and scientific laboratories.

The subject of statistical technique and procedure is treated under five main divisions; the difference of two means, differences among several means, relationship among variables, systematic quality control, and sampling and the risks of producers and buyers.

The manuscript of this book has for the past several years formed the basis of a course in industrial statistics given at the Massachusetts Institute of Technology.

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Acme and Other Translating Threads

Prepared by the sectional committee on the Standardization and Unification of Screw Threads (B1) *of the American Standards Association. Approved by the Association, September,* 1941, *Published by the American Society of Mechanical Engineers, 29 West 39 St., New York, N. Y. Price,* 45 *cents.*

Known as ASA B1.3–1941 this standard describes and defines scope and purpose of Acme and similar threads primarily used as translating screws. Outline drawings of profiles, basic dimensions and tolerances are given for general purpose acme threads, 29 deg. stub threads, 60 deg. stub threads, and 10 deg. modified square thread. Nomenclature is also listed and defined.

New Welding Standards

Prepared by technical committees of the American Welding Society. Both standards are published in bulletin form by the American Welding Society, 33 West 39th St., New York, N. Y. Price per copy 40 *cents.*

"Standard Methods for Mechanical Testing of Welds" describes in detail the principal mechanical tests applied to welds, including tests for density, soundness, tensile strength, shearing strength and ductility.

"Definitions of Welding Terms and Master Chart of Welding Processes" gives the standard definitions of welding terms adopted by the American Welding Society. This booklet also includes a chart showing the various subdivisions of the principal welding processes, namely; forge welding, resistance welding, arc welding, gas welding, thermit welding and brazing.

Aluminum Alloys for Aircraft

T. L. FRITZLEN—30 *pages,* 4¾x7¾ *in. Paper covers. Reprint of paper presented at tenth annual meeting of the Institute of Aeronautical Sciences. Available from Reynolds Metals Company, Louisville, Ky.*

Manufacture of aluminum from bauxite to the finished cast or wrought metal is described briefly. Includes the effects of working, alloying, annealing and heat treating. Fabrication procedures, specifications, inspection and uses for sheet and plate, rolled rod, extruded rod, bar and shapes and tubing are presented in some detail. Three tables of properties are also included.

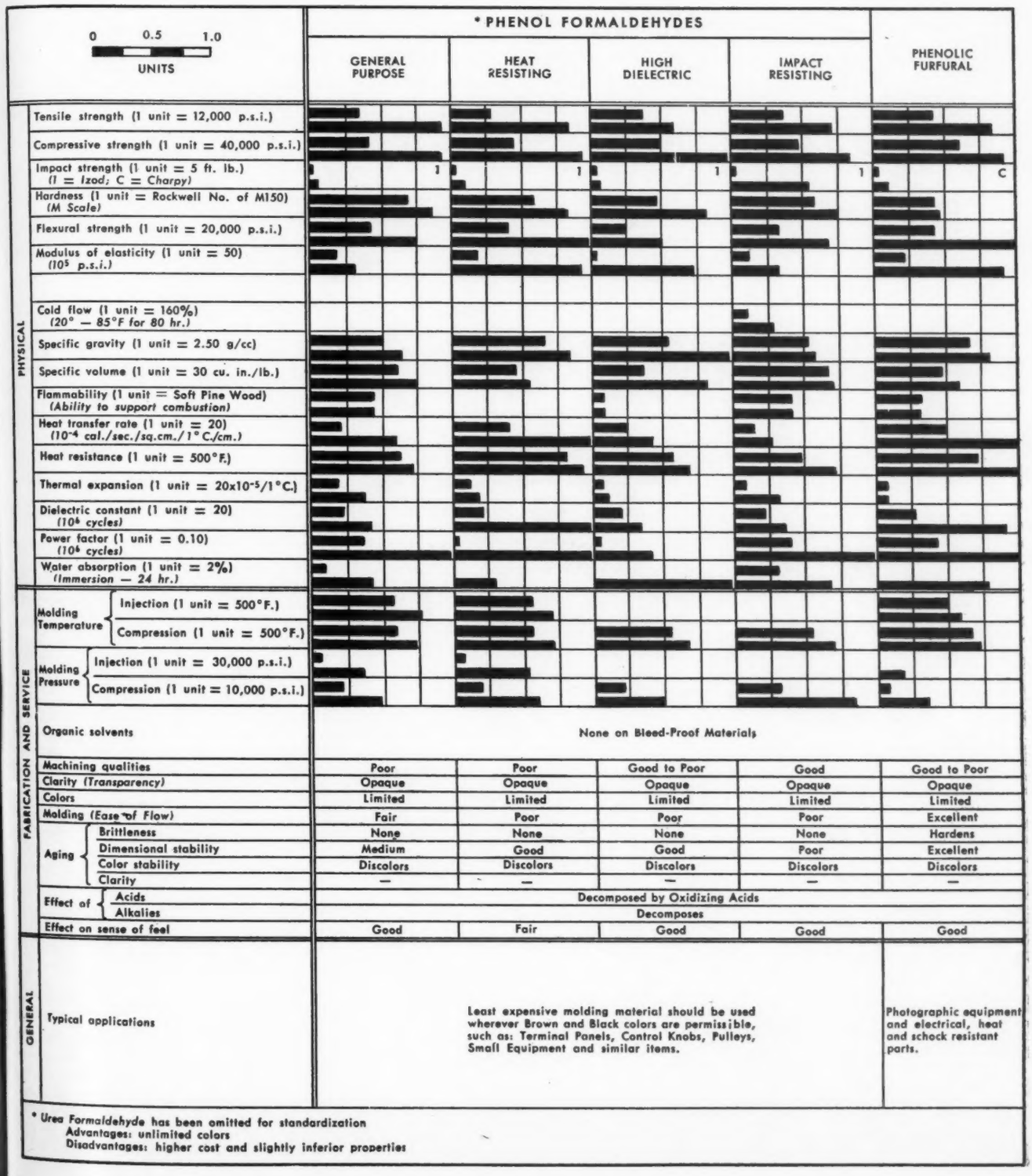
Inspection of Fusion Welding

Prepared by committee on Recommended Practices for Inspection of Welding. Published by the American Welding Society, 33 West 39 Street, New York, N. Y. Price, 40 *cents.*

The full title of this report is "Recommended Practices for Inspection of Fusion Welding." It is a comprehensive treatment of the many factors involved in the inspection of welds made by the arc and oxyacetylene processes. A considerable part of the report deals with the welding characteristics of both ferrous and non-ferrous metals. These sections describe the principal types of defects that may be encountered, indicate their usual causes, and state how they may be remedied.

Properties of Thermosetting Materials

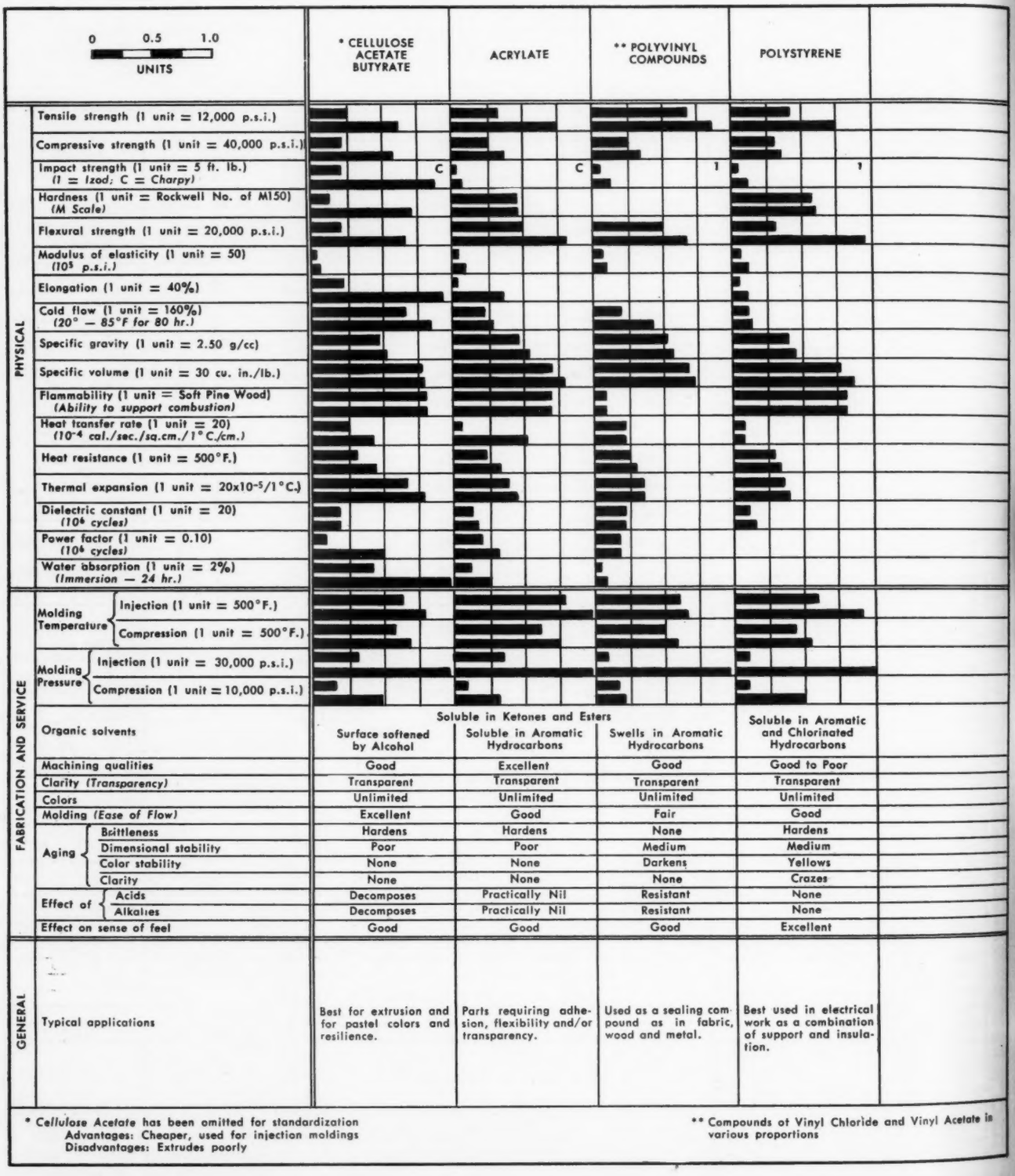
HORACE C. HILLMAN
Production Engineer, Lockheed Aircraft Corporation



* *Urea Formaldehyde* has been omitted for standardization
Advantages: unlimited colors
Disadvantages: higher cost and slightly inferior properties

Properties of Thermoplastic Materials

HORACE C. HILLMAN
Production Engineer, Lockheed Aircraft Corporation


0 0.5 1.0
UNITS
* CELLULOSE ACETATE BUTYRATE
ACRYLATE
** POLYVINYL COMPOUNDS
POLYSTYRENE
PHYSICAL
Tensile strength (1 unit = 12,000 p.s.i.)
Compressive strength (1 unit = 40,000 p.s.i.)
Impact strength (1 unit = 5 ft. lb.) (I = Izod; C = Charpy)
Hardness (1 unit = Rockwell No. of M150) (M Scale)
Flexural strength (1 unit = 20,000 p.s.i.)
Modulus of elasticity (1 unit = 50) (10⁵ p.s.i.)
Elongation (1 unit = 40%)
Cold flow (1 unit = 160%) (20° — 85°F for 80 hr.)
Specific gravity (1 unit = 2.50 g/cc)
Specific volume (1 unit = 30 cu. in./lb.)
Flammability (1 unit = Soft Pine Wood) (Ability to support combustion)
Heat transfer rate (1 unit = 20) (10⁻⁴ cal./sec./sq.cm./1°C./cm.)
Heat resistance (1 unit = 500°F.)
Thermal expansion (1 unit = 20x10⁻⁵/1°C.)
Dielectric constant (1 unit = 20) (10⁶ cycles)
Power factor (1 unit = 0.10) (10⁶ cycles)
Water absorption (1 unit = 2%) (Immersion — 24 hr.)
FABRICATION AND SERVICE
Molding Temperature
Injection (1 unit = 500°F.)
Compression (1 unit = 500°F.)
Molding Pressure
Injection (1 unit = 30,000 p.s.i.)
Compression (1 unit = 10,000 p.s.i.)
GENERAL

	* Cellulose Acetate Butyrate	Acrylate	** Polyvinyl Compounds	Polystyrene
Organic solvents	Soluble in Ketones and Esters; Surface softened by Alcohol	Soluble in Aromatic Hydrocarbons	Swells in Aromatic Hydrocarbons	Soluble in Aromatic and Chlorinated Hydrocarbons
Machining qualities	Good	Excellent	Good	Good to Poor
Clarity (Transparency)	Transparent	Transparent	Transparent	Transparent
Colors	Unlimited	Unlimited	Unlimited	Unlimited
Molding (Ease of Flow)	Excellent	Good	Fair	Good
Aging — Brittleness	Hardens	Hardens	None	Hardens
Aging — Dimensional stability	Poor	Poor	Medium	Medium
Aging — Color stability	None	None	Darkens	Yellows
Aging — Clarity	None	None	None	Crazes
Effect of — Acids	Decomposes	Practically Nil	Resistant	None
Effect of — Alkalies	Decomposes	Practically Nil	Resistant	None
Effect on sense of feel	Good	Good	Good	Excellent
Typical applications	Best for extrusion and for pastel colors and resilience.	Parts requiring adhesion, flexibility and/or transparency.	Used as a sealing compound as in fabric, wood and metal.	Best used in electrical work as a combination of support and insulation.

* *Cellulose Acetate* has been omitted for standardization
Advantages: Cheaper, used for injection moldings
Disadvantages: Extrudes poorly

** Compounds of Vinyl Chloride and Vinyl Acetate in various proportions

PRODUCT ENGINEERING ✦ REFERENCE BOOK SHEET